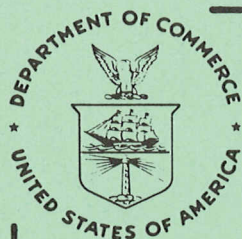


# NOAA Technical Memorandum NMFS-SEFC- 27



## NOAA/NMFS FINAL REPORT TO DOE

# Biological/Chemical Survey of Texoma and Capline Sector Salt Dome Brine Disposal Sites Off Louisiana, 1978-1979

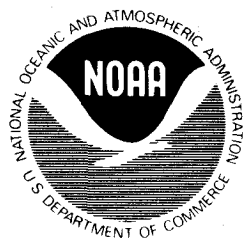
A report to the Department of Energy on work conducted under provisions  
of Interagency Agreement EL-78-I-O-7146 during 1978-1979.

## Volume III BACTERIA

NOVEMBER 1980



U.S. DEPARTMENT OF COMMERCE  
National Oceanic and Atmospheric Administration  
National Marine Fisheries Service  
Southeast Fisheries Center  
Galveston Laboratory  
Galveston, Texas 77550



# **NOAA Technical Memorandum NMFS-SEFC- 27**

## **Biological/Chemical Survey of Texoma and Capline Sector Salt Dome Brine Disposal Sites Off Louisiana, 1978-1979**

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### **VOL. III -DESCRIBE BACTERIAL COMMUNITIES BY**

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**A report to the Department of Energy on work conducted under provisions  
of Interagency Agreement EL-78-1-0-7146 during 1978-1979.**

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and Capline sector salt dome brine disposal sites off Louisiana,  
1978-1979. NOAA Technical Memorandum NMFS-SEFC-27, 48 p.  
Available from: NTIS, Springfield, Virginia.

# Volume III - BACTERIA

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## LIST OF VOLUMES

This Final Report is printed in nine separate volumes:

### Volume I - BENTHOS

Work Unit 2.1 Describe Living and Dead Benthic (Macro- and Meio-) Communities

Coastal Ecosystems Management, Inc.

R. H. Parker, Ph.D.

A. L. Crowe

L. S. Bohme

### Volume II - ZOOPLANKTON

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Concentration in Major Components of the  
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Nutrients Composition and Concentrations in  
the Water Column

Texas A & M University

J. M. Brooks, Ph.D.

Volume IX - SHRIMP DATA ANALYSIS

Work Unit 5.1 Analysis of Variance of Gulf Coast Shrimp Data

LGL Ecological Research Associates, Inc.

F. J. Margraf, Ph.D.

## INTRODUCTION

In compliance with the Energy Policy and Conservation Act of 1975, Title 1, Part B (Public Law 94-163), the Department of Energy (DOE) implemented the Strategic Petroleum Reserve (SPR). The SPR program was implemented in August of 1977 with the goal of storing a minimum of one billion barrels of crude oil by December 22, 1982. After evaluating several physical storage possibilities, DOE determined that storage in commercially developed salt dome cavities through solution-mining processes was the most economically and environmentally advantageous option.

Six areas along the northwestern Gulf of Mexico were to be investigated as potential storage cavern sites. These areas are shown in Figure 1. This project, "Biological/Chemical Survey of Texoma and Capline Sector Salt Dome Brine Disposal Sites Off Louisiana", deals with proposed disposal sites associated with two of the cavern sites, West Hackberry and Weeks Island. The Biological/ Chemical Survey was initiated in April 1978 and was completed in December 1979. Its major products are Final Reports available through the National Technical Information Service (NTIS), Springfield, Virginia; data files available through the Environmental Data and Information Service (EDIS), Washington, D.C., and any research papers that may be written by participating principal investigators and published in scientific or technical journals. Preliminary results were also made available through DOE/NOAA/NMFS project reviews and workshops attended by project participants and various governmental, private and public user groups.

The objectives of the Biological/Chemical Survey were: (1) to describe the biological, physical and chemical components of the marine ecosystem for each disposal site; and (2) to assess, by analysis of Gulf Coast shrimp data, the importance of the Louisiana shrimping grounds in the vicinity of the proposed salt dome brine disposal sites. These objectives were achieved using historical and new data to describe and quantify the biological, chemical, and physical characteristics and the temporal variations of these characteristics in the environments of each proposed disposal site.

The two proposed disposal sites have been extensively examined, using available meteorological, oceanographic, bathymetric and ecological data, in the following two reports:

Environmental Data Service, DOC/NOAA. 1977.

Analysis of Brine Disposal in the Gulf of Mexico, #2 West Hackberry. Report to Federal Energy Administration Strategic Petroleum Reserve Program Salt Dome Storage. Center for Experiment Design and Data Analysis, NOAA, EDS, Marine Assessment Division, Washington, D.C.

Environmental Data Service, DOC/NOAA. 1977.

Analysis of Brine Disposal in the Gulf of Mexico, #3 Capline Sector. Report to Federal Energy Administration Strategic Petroleum Reserve Program Salt Dome Storage. Center for Experiment Design and Data Analysis, NOAA, EDS, Marine Assessment Division, Washington, D.C.

The above reports and other pertinent documents are available from the Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia, 22151.

Proposed locations of the West Hackberry (Texoma Sector) and Weeks Island (Capline Sector) brine disposal sites are shown in Figures 2 and 3, respectively. These sites are subject to change within the same geographic area pending results of baseline surveys presently underway.

The proposed West Hackberry disposal site is located approximately 9.7 km (6 miles) south off the coast from Mud Lake at Latitude  $29^{\circ}40' N$  and Longitude  $93^{\circ}28' W$  at a bottom depth of about 9 m (30 feet). Operational requirements and engineering limitations of the proposed brine diffuser at this site are as follows: length - 933.3 m (3070 feet); orientation -normal to coast; number of ports - 52; length between ports - 18 m (59 feet); port diameter - 7.6 cm (3 inches); orientation of port riser -  $90^{\circ}$  to bottom; and port exit velocity - 7.6 m/sec (25 ft/sec).

The proposed Weeks Island (Capline Sector) disposal site is located approximately 41.8 km (26 miles) off Marsh Island at Latitude  $29^{\circ}04' N$  and Longitude  $91^{\circ}45' W$  at a bottom depth of about 9 m (30 feet). Operational requirements and engineering limitations of the proposed brine diffuser at this site are as follows: length - 608 m (2000 feet); orientation -normal to coast; number of ports - 34; orientation to port riser -  $90^{\circ}$  to bottom, and port exit velocity - 7.6 m/sec (25 ft/sec).

The Biological/Chemical Surveys in the proposed salt dome brine disposal sites described seasonal abundance, distribution and community

composition of major benthic, planktonic, bacterial and demersal finfish and macro-crustacean ecosystem components; the sediments; the hydrocarbons and trace metals composition and concentration in the marine ecosystem; and the seasonal variations in inorganic nutrients composition and concentration of the water column. The sampling scheme used for sample collections around the two sites is shown in Figure 4. A separate data analysis assessed the importance of shrimp-ing grounds in the vicinity of the proposed brine disposal sites in terms of historical data on species composition, marketing size categories and location of commercial shrimp catches within statistical reporting zones off the Louisiana coast.

Information concerning data from this project is available through the Program Data Manager: Mr. Jack Foreman, Environmental Data and Information Service, Page Building No. 2, 3300 Whitehaven Street, N.W., Washington, D.C.

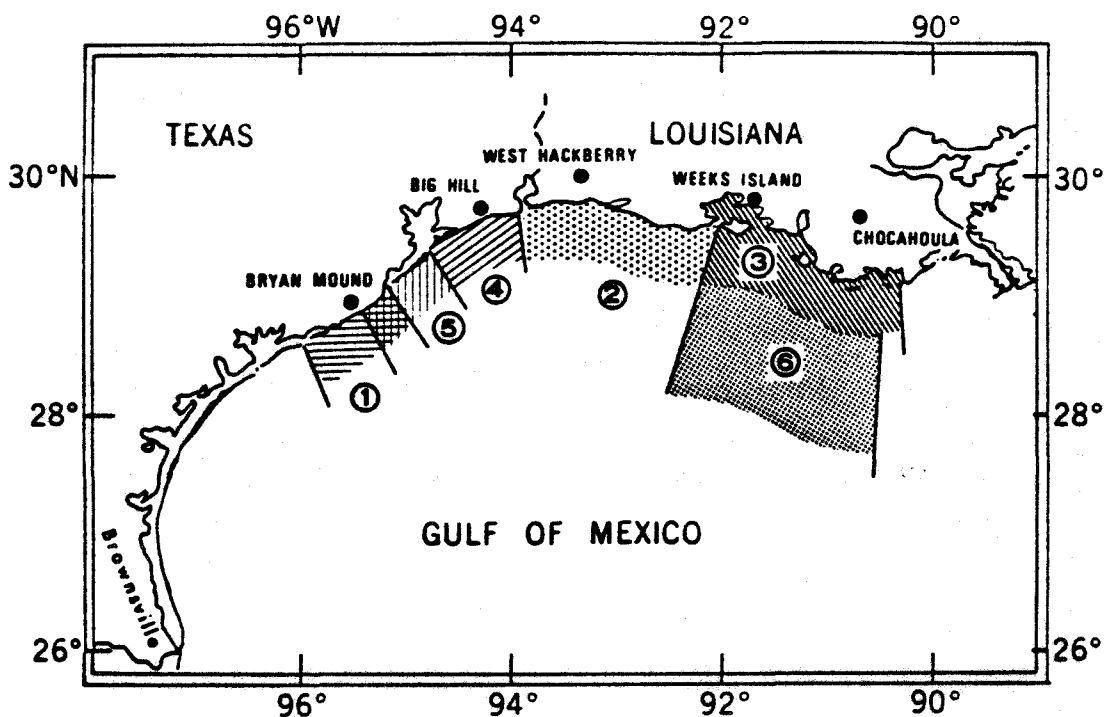


Figure 1. Regions of Study for Brine Disposal Assessment-DOE/NOAA Interagency Agreement (adapted from Environmental Data Service, DOC/NOAA. Analysis of Brine Disposal in the Gulf of Mexico, #2 West Hackberry. 1977.).

- 1 Texas Coastal Ocean, Colorado River to San Luis Pass (Bryan Mound)
- 2 Louisiana Coastal Ocean, Sabine Lake to S.W. Pass of Vermilion Bay (West Hackberry)
- 3 Louisiana Coastal Ocean, S.W. Pass, Vermilion Bay to Timbalier Island (Capline Sector)
- 4 Texas Coastal Ocean, Port Bolivar to Sabine Pass
- 5 Texas Coastal Ocean, Freeport Harbor to Galveston South Jetty
- 6 Louisiana Coastal Ocean, Offshore from Vermilion Bay to Terrebone Bay

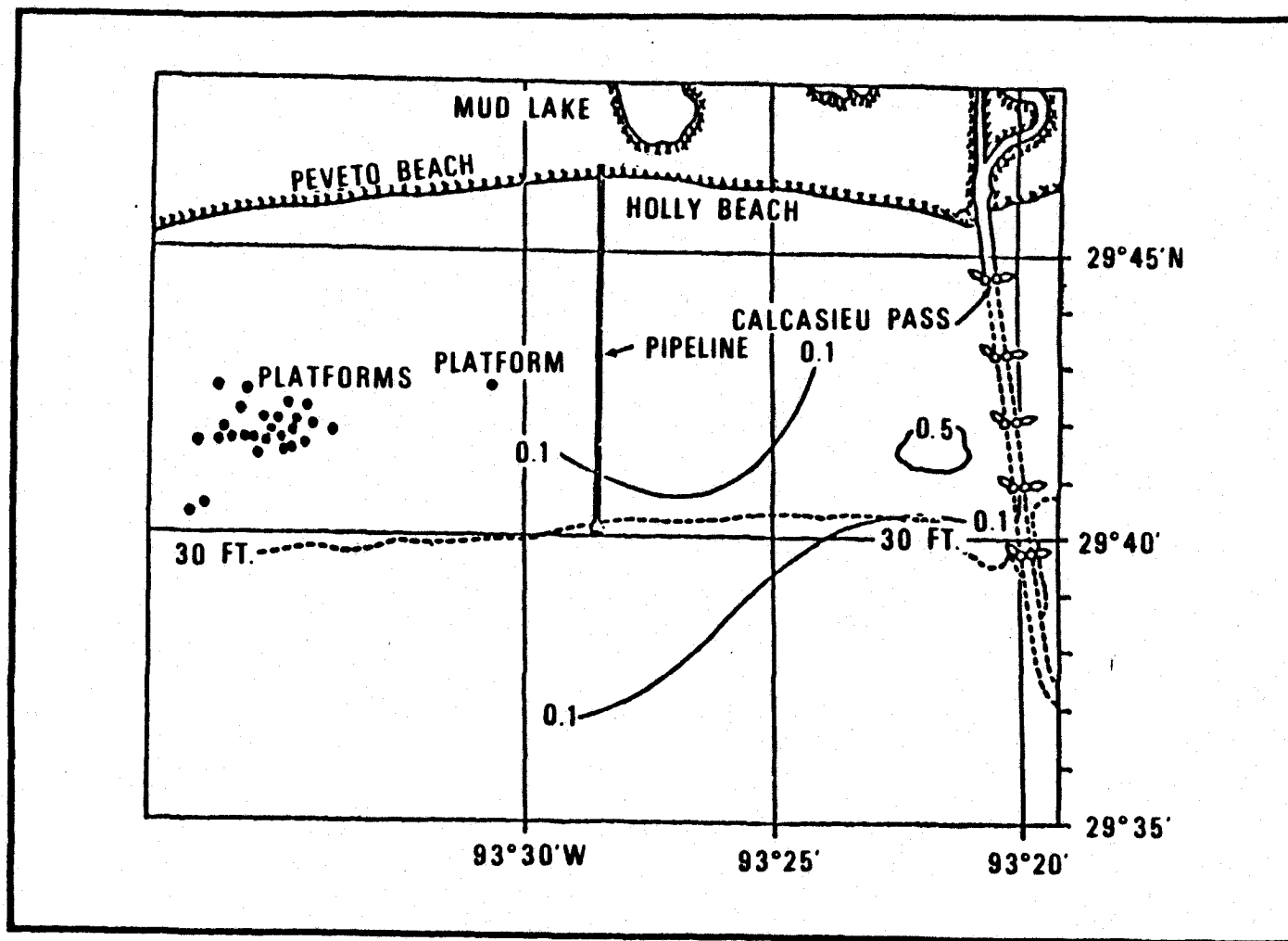


Figure 2. Proposed Texoma brine disposal site.

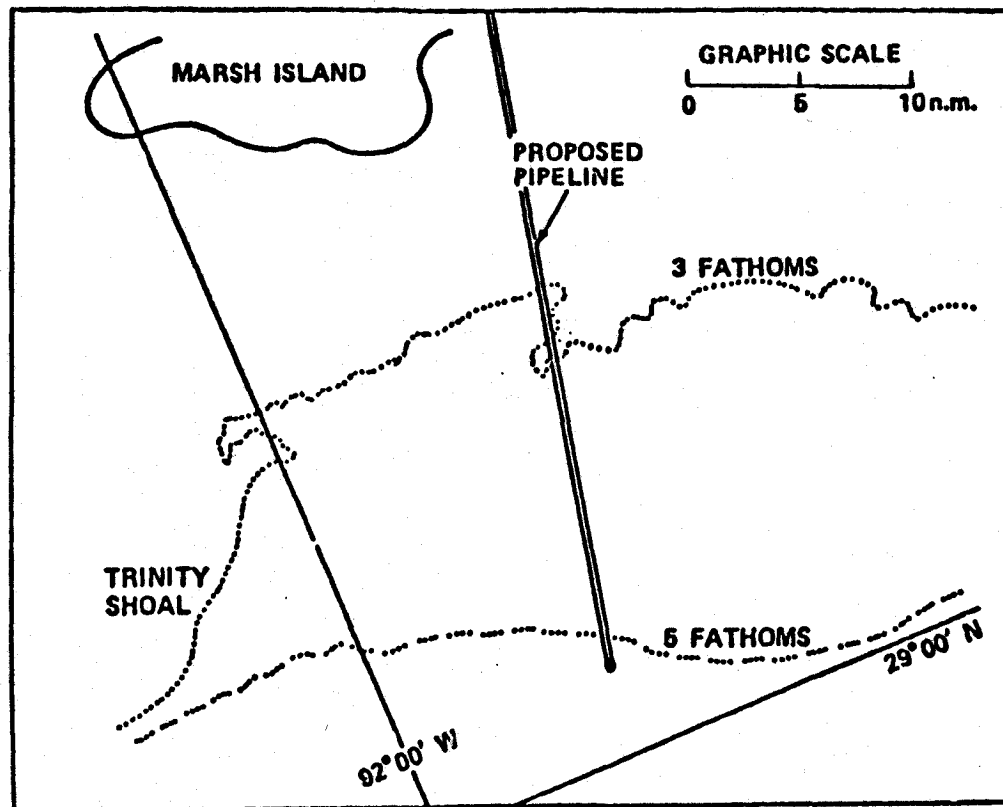


Figure 3. Proposed Capline brine disposal site.

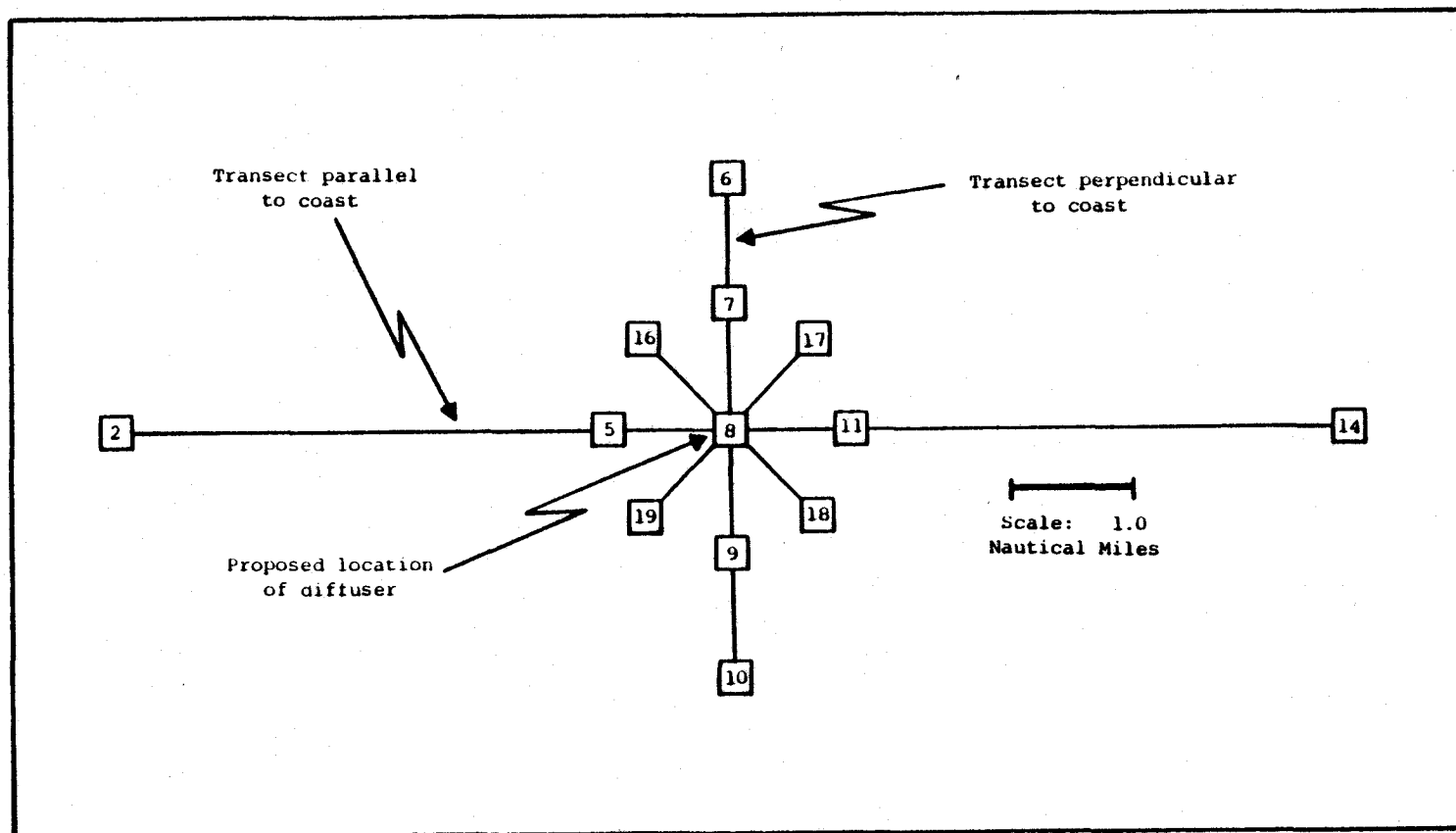


Figure 4. Sampling scheme for proposed salt dome brine disposal sites.

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## II. PRINCIPAL INVESTIGATORS' SECTION

WORK UNIT 2.3 - DESCRIBE BACTERIAL COMMUNITIES

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## ABSTRACT

A 1-year study was made of bacterial populations present at two proposed brine disposal sites off Louisiana: West Hackberry and Weeks Island.

Aerobic heterotrophic bacteria of sediment ranged from  $1.2 \times 10^5$  to  $6.4 \times 10^7$ /ml at the West Hackberry site, and from  $2.0 \times 10^3$  to  $1.5 \times 10^8$ /ml at the Weeks Island site. Sediment bacterial populations were most numerous during summer, corresponding to maximum mean in situ temperatures. Greatest levels during all seasons occurred at the West Hackberry site, where the substrate was finer textured and contained a higher organic content.

Aerobic heterotrophic bacteria in water ranged from  $2.6 \times 10^2$  to  $2.1 \times 10^4$ /ml at the West Hackberry site, and from  $1.0 \times 10^2$  to  $1.4 \times 10^4$ /ml at the Weeks Island site. The seasonal distribution of water bacteria (highest during winter) suggests that these populations are influenced largely by mixing processes that resuspend particles.

Hydrocarbon degrading bacteria were an indigenous component of the benthic bacterial population throughout the year. Populations ranged from  $3.0 \times 10^2$  to  $2.0 \times 10^5$ /ml at the West Hackberry site, and from  $6.0 \times 10^2$  to  $8.9 \times 10^5$ /ml at the Weeks Island site. Maximum levels were recorded during summer-fall. Hydrocarbon degrading bacterial populations in sediment did not correspond to relative levels of hydrocarbons present at the two sites.

Sediment from the two study sites contained a resident population of halophilic (salt-tolerant) bacteria capable of growth in 50 o/oo salt. Populations ranged from  $4.9 \times 10^4$  to  $4.1 \times 10^6$ /ml at the West Hackberry site, and from  $8.0 \times 10^2$  to  $4.7 \times 10^6$ /ml at the Weeks Island site. Halophiles in sediment exhibited seasonal and spatial variations similar to those of the aerobic heterotrophic population.

Photosynthetic bacteria were isolated from the two study sites. However, these bacteria were neither prevalent nor numerous, being isolated only occasionally and never in numbers exceeding 10/ml wet sediment.

Members of the genus Bacillus were the predominant aerobic heterotrophic and halophilic bacteria isolated from West Hackberry site sediment, while Vibrio sp. were the predominant isolates from Weeks Island site sediment. The predominant hydrocarbon degrading bacteria from both sites were Pseudomonas sp. Aerobic heterotrophic bacteria isolated from water of both sites were predominantly species of Vibrio.

The bacterial diversity of sediment ranged from 0.38 to 1.93 at the West Hackberry site, and from 0.12 to 2.06 at the Weeks Island site. Diversity was at a maximum during summer-fall. The bacterial diversity of water ranged from 0.14 to 2.15 at the West Hackberry site, and from 0.15 to 2.10 at the Weeks Island site. Highest diversity of water bacteria occurred during fall. There were no consistent differences between sites in the bacterial diversity of sediment or water.

The heterotrophic activity (mean uptake rate of  $^{14}\text{C}$ -(U) glucose) of sediment ranged from 0 to  $1784 \times 10^2$  dpm/ml/hr at the West Hackberry site, and from 0 to  $834 \times 10^2$  dpm/ml/hr at the Weeks Island site. Highest heterotrophic activity occurred during summer. Mean uptake rates were

greatest at the West Hackberry site during all seasons, but these differences were significant only during winter.

The heterotrophic activity of water ranged from 0 to 69.3 dpm/ml/hr at the West Hackberry site, and from 0 to 403.7 dpm/ml/hr at the Weeks Island site. There were no significant seasonal variations and no consistent differences between sites.

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## INTRODUCTION

The Strategic Petroleum Reserve (SPR) of the Department of Energy was implemented in 1975 to buffer the impact of future oil shortages. The SPR goal is to store 750 million barrels of crude oil in salt domes along the Gulf Coast of Texas and Louisiana (Carter, 1979). Huge caverns would be created in salt dome structures by injecting large quantities of water. The resultant brine would be pumped out of the cavity and routed to offshore disposal sites via a pipeline. The impact of such offshore brine disposal on the marine ecosystem is of particular concern. For this reason, pre-disposal surveys of selected physical, chemical, and biological parameters at proposed offshore sites have been conducted to provide baseline information for post-disposal monitoring studies. A description of these surveys is given in the Program Development Plan, SPR Brine Disposal Analysis Program, U. S. Department of Commerce. The present report presents results from the pre-disposal survey of the bacterial communities at the proposed Texoma and Capline Sector salt dome brine disposal sites off Louisiana.

Bacteria are an integral part of the marine ecosystem, serving as food for a variety of marine organisms (Zobell and Feltham, 1938; Newell, 1965; Odum, 1970; Chua and Brinkhurst, 1973) and as major mineralizers of organic matter (Wright, 1974). Offshore brine disposal may effect the growth and activity of resident bacteria, thus disrupting their normal ecosystem functions. Although marine bacteria require 2.5-4.0% salt (specifically NaCl) for optimum growth, high salt concentrations may be detrimental. For example, salt concentrations in excess of 5% can decrease bacterial viability (Zobell, 1946), slow microbial growth (Rheinheimer, 1974), and inhibit biodegradation of hydrocarbons (Ward and Brock, 1978).

The primary objective of the present study was to provide a qualitative and quantitative description of the bacterial communities present at two sites off the Louisiana coast prior to proposed brine disposal. Comparison of pre-disposal data from the present study with post-disposal data from future monitoring studies will aid in assessing the impact of brine on the resident bacterial communities.

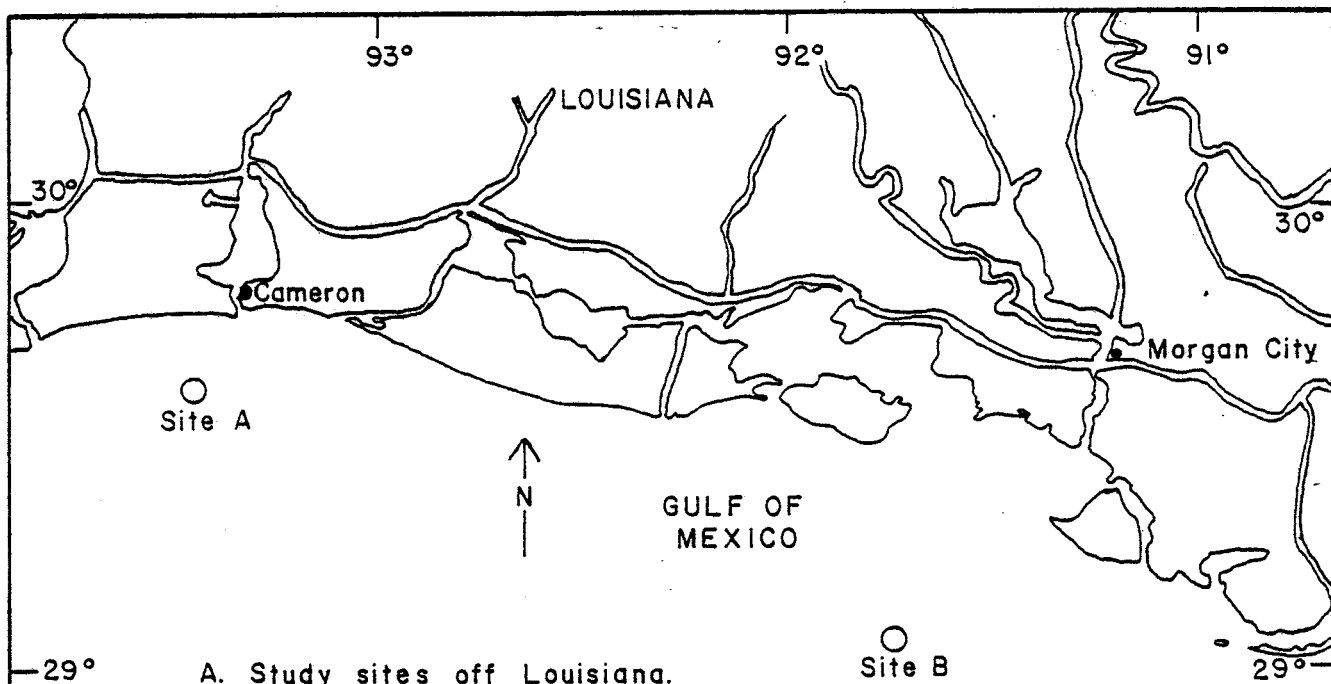
The following aspects of the bacterial community were examined at the two study sites: (1) populations of aerobic heterotrophic, hydrocarbon degrading, halophilic (salt-tolerant), and photosynthetic bacteria; (2) predominant bacterial genera; (3) bacterial diversity; and (4) heterotrophic activity. This report represents the first intensive bacteriological investigation of the two study sites off Louisiana.

## MATERIALS AND METHODS

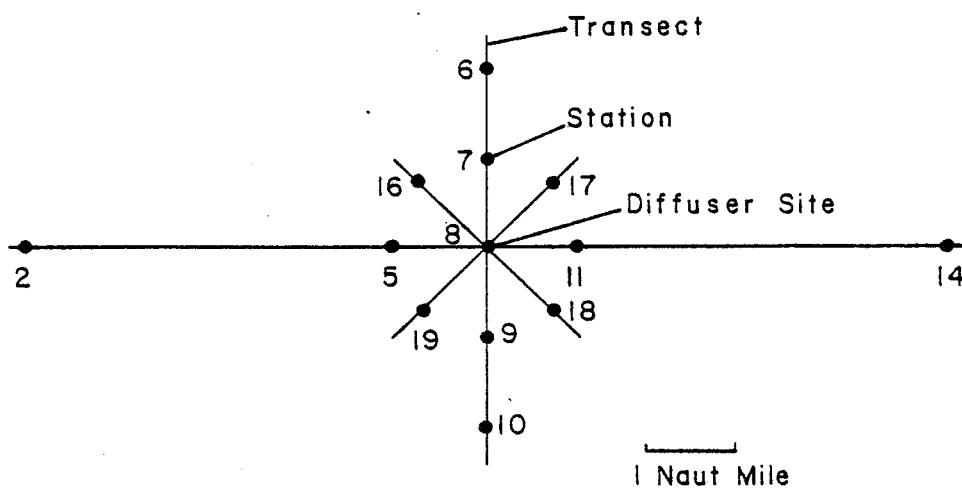
### Sampling

The geographic location of the two study sites off Louisiana is depicted in Figure 1. The West Hackberry site (A) is located at 29°40'N and 93°28'W, or approximately 6 miles southwest of Holly Beach, Louisiana. The Weeks Island site (B) is located at 29°04'N and 91°45'W, or approximately 26 miles from the south point of Marsh Island, Louisiana. Thirteen stations, distributed along four transects at distances of 1, 2, and 5 miles from the proposed brine diffuser, were sampled at each site (Figure 1).

Sediment and water were collected at each station during the summer, fall, winter, and spring 1978-1979 (23-29 June; 3, 12-16 October, 8-11 November; 24-29 January; and 28 April - 3 May, respectively). Station characteristics for all sediment and water samples collected during these seasons are given in Appendix Tables 1, 2, 3, and 4, respectively.



A. Study sites off Louisiana.



B. Station array at the study sites.

Figure 1. Sampling stations.

Station depth was recorded prior to sample collection either by marked hydro-wire or vessel fathometer. Water was collected at mid-depth with a Niskin sterile bag sampler (General Oceanics, Miami, Florida). After sampler retrieval, water was transferred to a sterile 250 ml Erlenmeyer flask. Subsamples were taken from this flask for water bacteriological analyses. Water temperature was measured with a mercury-filled glass thermometer, while salinity was determined with a Goldberg T/C refractometer (American Optical, Buffalo, New York).

Sediment was collected with a Van Veen grab and its temperature determined with a mercury-filled glass thermometer immediately after sample retrieval. The top 1 cm of sediment, away from the walls of the grab, was removed with a spatula and placed into a sterile 37 ml sample jar. A 1:10 dilution of sediment was prepared in a 500 ml Erlenmeyer flask. Subsamples were taken from this flask for sediment bacteriological analyses.

Processing of sediment and water was initiated immediately after collection to minimize alteration of bacterial numbers and activity (Zobell, 1946). Processing was completed within one hour of collection, with the exception of samples collected during fall from the Weeks Island site. These samples were held on ice until analysis, within 48 hours. Procedures initiated immediately after sample collection were: (1) inoculation of plates, tubes, and bottles with sediment and water dilutions for subsequent determination of number, genera, and diversity of bacteria; and (2) inoculation of serum vials with sediment and water for subsequent determination of heterotrophic activity. After inoculation, materials were secured for subsequent transfer to the laboratory.

Contamination of culture media during on-board processing and subsequent transfer was monitored at each station. The number of bacteria

arising on the uninoculated marine agar medium was less than 10% of the number arising on the inoculated medium at 85 of the 104 stations occupied. The number of bacteria arising on the uninoculated halophilic medium was less than 7% of the number arising on the inoculated medium at 102 of the 104 stations occupied. Therefore, contamination of culture media was only a problem at a small percentage of the stations.

#### Enumeration of bacteria

Total aerobic heterotrophic bacteria. Two subsamples of sediment and one of water were serially diluted in artificial seawater (Instant Ocean) and three dilutions spread-plated in triplicate onto Marine Agar 2216 (DIFCO). Bacterial colonies were enumerated with a Quebec Colony Counter after 10 days incubation at the seasonal mean in situ temperature (Table 1).

Hydrocarbon degrading bacteria. The most-probable-number (MPN) technique, described by Gunkel (1973), in the three-tube series was used for enumeration of hydrocarbon degrading bacteria of sediment. Three subsamples of sediment were serially diluted in artificial seawater and 1 ml of four sediment dilutions placed into tubes containing 10 ml basal medium and 0.05 ml South Louisiana crude oil. The basal medium consisted of 1g  $\text{NH}_4\text{NO}_3$  and 1g  $\text{KH}_2\text{PO}_4$  per liter artificial seawater. The pH of the medium was adjusted to 7.6 by the addition of 1N NaOH prior to use. After inoculation, tubes were incubated stationary for 30 days at the seasonal mean in situ temperature. Positive tubes were determined by visual observation of growth, i.e., presence of a pellicle or turbidity.

Three tubes without added oil were inoculated at each station with the lowest sediment dilution. These tubes consistently exhibited either negligible or no growth. Therefore, growth in tubes that contained oil was considered to be a result of hydrocarbon degradation, and not due to

TABLE 1

Temperature of sediment and water collected from the two study sites during 1978-1979. Each tabulated value represents the mean  $\pm 1$  standard deviation of 13 stations.

<u>Site</u>	<u>Sample</u>	Temperature ( $^{\circ}\text{C}$ )			
		<u>Summer</u>	<u>Fall</u>	<u>Winter</u>	<u>Spring</u>
A	Sediment	28 $\pm$ 1	26 $\pm$ 1	10 $\pm$ 1	22 $\pm$ 1
	Water	29 $\pm$ 1	26 $\pm$ 1	10 $\pm$ 1	23 $\pm$ 1
B	Sediment	28 $\pm$ 1	23 $\pm$ 1	12 $\pm$ 1	22 $\pm$ 1
	Water	30 $\pm$ 1	22 $\pm$ 1	11 $\pm$ 1	22 $\pm$ 1

the addition of nutrients in the sediment inoculum.

Percent hydrocarbon degrading bacteria. Total aerobic heterotrophic and hydrocarbon degrading bacteria of sediment were enumerated as described above. The mean number of hydrocarbon degrading bacteria per milliliter wet sediment was divided by the mean number of aerobic heterotrophic bacteria per milliliter wet sediment. The ratio obtained was multiplied by 100 to obtain the percent hydrocarbon degrading bacteria.

Halophilic bacteria. Two subsamples of sediment were serially diluted in artificial seawater and three dilutions spread-plated in triplicate onto a medium of the following composition: 20g NaCl, 5g peptone, 1g yeast extract, and 15g agar per liter artificial seawater (pH adjusted to 7.6). Bacterial colonies were enumerated with a Quebec Colony Counter after 10 days incubation at the seasonal mean in situ temperature.

The salinity of the above medium was 50 o/oo. This is 20-32 o/oo greater than the mean salinity of mid-depth water collected from the two study sites (Table 2). Bacteria capable of growth on this medium, therefore, are considered to be halophilic (salt-tolerant).

Percent halophilic bacteria. The total aerobic heterotrophic and halophilic bacteria of sediment were enumerated as outlined above. The mean number of halophilic bacteria per milliliter wet sediment was divided by the mean number of aerobic heterotrophic bacteria per milliliter wet sediment. The ratio obtained was multiplied by 100 to obtain the percent halophilic bacteria.

Photosynthetic bacteria. The medium of Aaronson (1970), employed during the summer for enumeration of photosynthetic bacteria, failed to detect these bacteria in sediment from the two study sites. For this reason, the medium of Pfennig, as described by Van Niel (1971), was tested during the fall. Pfennig's medium detected photosynthetic bacteria at

TABLE 2

Salinity of mid-depth water collected from the two study sites during 1978-1979. Each tabulated value represents the mean  $\pm 1$  standard deviation of 13 stations.

<u>Site</u>	<u>Salinity (o/oo)</u>			
	<u>Summer</u>	<u>Fall</u>	<u>Winter</u>	<u>Spring</u>
A	19 $\pm$ 2	28 $\pm$ 1	23 $\pm$ 2	19 $\pm$ 2
B	19 $\pm$ 3	30 $\pm$ 1	25 $\pm$ 4	18 $\pm$ 1

several stations. Therefore, the latter medium was utilized for the enumeration of photosynthetic bacteria for the remainder of the study.

Triplicate screw cap bottles (30 ml) containing Pfennig's medium were inoculated with 1 ml of serial sediment dilutions. Bottles were capped tightly after inoculation and incubated stationary for 30 days on a laboratory window-sill. Positive bottles were determined by (1) visual observation of green, red, purple, or brown-colored patches of growth, and (2) microscopic verification that colored patches contained concentrations of bacteria.

#### Predominant bacterial genera

Marine Agar 2216 plates, used for enumeration of total aerobic heterotrophic bacteria, were used as the source for obtaining pure cultures from sediment and water. Isolates were selected on the basis of colonial morphology and maintained on marine agar slants prior to identification.

Positive basal-oil tubes were used as a source for obtaining pure cultures of hydrocarbon degrading bacteria. Growth in tubes was streaked onto Marine Agar 2216. Isolated colonies were tested for growth in fresh basal-oil tubes. Isolates exhibiting growth in the fresh medium were considered hydrocarbon degraders and were maintained in the basal-oil medium for identification.

The medium used for enumeration of halophilic bacteria was used as the source for isolating pure cultures. Isolates were selected on the basis of colonial morphology and maintained for identification.

Bacterial isolates were identified to generic level according to Bergey's Manual of Determinative Bacteriology (1974). This entailed the performance of approximately 20 morphological, physiological, and biochemical tests for each pure culture.

### Bacterial diversity

Colonies arising on Marine Agar 2216 were used to calculate the bacterial diversity of sediment and water. Two diversity indices were used (Odum, 1971): Index (1)  $D = S/\sqrt{N}$ , and Index (2)  $D = (S-1)/\log N$ , where D is the diversity index, S is the number of colony types, and N is the total number of colonies. The number of colony types (based on shape, form, edge, pigmentation, opaqueness, tint, etc.) and the total number of colonies were determined for six replicate sediment and three replicate water plates per station.

### Heterotrophic activity

Four subsamples of sediment (10 ml of a 1:100 dilution prepared in artificial seawater) and four of water (10 ml, undiluted) were added to separate 30 ml serum vials (8 total) containing 100 $\mu$ g/l  $^{14}\text{C}$ -(U) glucose (specific activity, 4.3 or 4.5 mCi/mmol, New England Nuclear, Boston, Massachusetts). One of the four vials receiving sediment and one of the four receiving water contained one drop of concentrated  $\text{H}_2\text{SO}_4$  and served as a control for abiotic processes. After the addition of samples, vials were sealed with a rubber stopper having a center well suspended beneath it containing a 20 x 60 mm piece of fluted filter paper. Vials were incubated stationary for 1 to 3 hours at ambient temperatures that were within 8°C of the mean seasonal in situ temperature.

The  $^{14}\text{CO}_2$  and bacteria in serum vials were collected after incubation using methodology of Hobbie and Crawford (1969). One drop of concentrated  $\text{H}_2\text{SO}_4$  was added to the fluid in vials (final pH, 1.6) via a syringe needle to terminate the reaction and drive  $^{14}\text{CO}_2$  out of solution. The  $^{14}\text{CO}_2$  liberated was collected by injecting 0.3 ml of phenethylamine onto the filter paper in the center well. The vials were left undisturbed for 12 to 24 hours to allow complete absorption of  $^{14}\text{CO}_2$  by the phenethyla-

mine. After this period, the filter paper was removed from the center well and placed in a liquid scintillation vial containing 10 ml of counting solution (4g OMNIFLUOR [New England Nuclear] per liter scintillation grade toluene). The bacteria were then collected by filtration through a 0.4 $\mu$  Nuclepore polycarbonate membrane (Nuclepore Corp., Pleasanton, California). The membrane was rinsed with 10 ml artificial seawater prior to addition to a liquid scintillation vial containing 10 ml counting solution.

The radioactivity in liquid scintillation vials was assayed with a Beckman LS 8100 liquid scintillation counter. The percent counting efficiency was determined for each scintillation vial by recounting after addition of 5 $\mu$ l  $^{14}\text{C}$ -toluene standard (activity,  $4.7 \times 10^5$  dpm/ml, New England Nuclear). Counts per minute were converted to disintegrations per minute (dpm) using the calculated percent efficiency. The radioactivity of the filter paper and membrane from the acid-killed serum vial of each set was subtracted from the remaining three serum vials. Rates of glucose utilization were then calculated and recorded as dpm of  $^{14}\text{C}$ -(U) glucose taken into the cell or mineralized to  $^{14}\text{CO}_2$  per ml of sample per hour incubation.

#### Statistical analysis

Analysis of variance was employed to evaluate seasonal variations in bacterial parameters at the two study sites, while the t-test was used to evaluate spatial distributions in bacterial parameters. All statistical procedures followed Steel and Torrie (1960). A significance level of .05 was considered necessary to establish a significant difference in all tests.

## RESULTS AND DISCUSSION

### Bacterial populations

Aerobic heterotrophic bacteria of sediment ranged from  $1.2 \times 10^5$  to  $6.4 \times 10^7$ /ml at the West Hackberry site, and from  $2.0 \times 10^3$  to  $1.5 \times 10^8$ /ml at the Weeks Island site (Appendix Table 5). Analysis of variance indicated a significant ( $P < .01$ ) seasonal difference in benthic bacterial populations at both sites with highest numbers during summer and lowest during winter (Table 3). There were also significant ( $P < .01$ ) spatial differences in benthic bacterial populations with differences between stations at each site (during all seasons) and between sites (greatest populations at the West Hackberry site during all seasons).

Hydrocarbon degrading bacteria were enumerated in all but one of the 104 sediment samples collected during the study. Populations ranged from  $3.0 \times 10^2$  to  $2.0 \times 10^5$ /ml at the West Hackberry site, and from  $6.0 \times 10^2$  to  $8.9 \times 10^5$ /ml at the Weeks Island site (Appendix Table 6). Analysis of variance demonstrated a significant ( $P < .05$ ) seasonal variation in hydrocarbon degrading populations at both sites with highest numbers during summer-fall and lowest during winter-spring (Table 3). There was a significant ( $P < .05$ ) difference between sites during summer, with highest populations at the Weeks Island site. There was, however, no significant difference between sites during the remaining three seasons.

The percent hydrocarbon degrading bacteria of sediment ranged from 0.04 to 21.3% at the West Hackberry site, and from 0.07 to 106.5% at the Weeks Island site (Appendix Table 7). Analysis of variance demonstrated a significant ( $P < .01$ ) seasonal variation in the percent hydrocarbon degrading bacteria at both sites with highest percentages during winter and lowest during spring-summer (Table 3). There was no significant difference between sites during spring-summer. There was, however,

TABLE 3

Bacterial populations of sediment from the two study sites during 1978-1979. Each tabulated value represents the mean  $\pm$  1 standard deviation of 13 stations.

Type	Season	Site	
		West Hackberry	Weeks Island
1. Aerobic heterotrophic bacteria (number/ml)	Summer	25.7 $\pm$ 25.8 $\times 10^6$	5.3 $\pm$ 4.4 $\times 10^6$
	Fall	7.5 $\pm$ 2.9 $\times 10^6$	2.0 $\pm$ 3.1 $\times 10^6$
	Winter	0.5 $\pm$ 0.3 $\times 10^6$	0.1 $\pm$ 0.1 $\times 10^6$
	Spring	12.1 $\pm$ 5.3 $\times 10^6$	4.4 $\pm$ 5.8 $\times 10^6$
2. Hydrocarbon degrading bacteria (number/ml)	Summer	6.2 $\pm$ 8.9 $\times 10^4$	17.2 $\pm$ 29.5 $\times 10^4$
	Fall	8.3 $\pm$ 8.1 $\times 10^4$	12.6 $\pm$ 25.1 $\times 10^4$
	Winter	2.5 $\pm$ 4.4 $\times 10^4$	1.3 $\pm$ 2.6 $\times 10^4$
	Spring	4.7 $\pm$ 3.7 $\times 10^4$	7.3 $\pm$ 19.9 $\times 10^4$
3. Percent hydrocarbon degrading bacteria	Summer	0.3 $\pm$ 0.3	5.6 $\pm$ 9.4
	Fall	1.2 $\pm$ 0.8	6.5 $\pm$ 6.6
	Winter	5.4 $\pm$ 6.3	23.4 $\pm$ 28.4
	Spring	0.6 $\pm$ 0.8	0.8 $\pm$ 0.9
4. Halophilic bacteria (number/ml)	Summer	12.2 $\pm$ 12.1 $\times 10^5$	4.4 $\pm$ 4.0 $\times 10^5$
	Fall	8.2 $\pm$ 8.7 $\times 10^5$	1.5 $\pm$ 2.8 $\times 10^5$
	Winter	1.3 $\pm$ 1.2 $\times 10^5$	0.2 $\pm$ 0.2 $\times 10^5$
	Spring	5.7 $\pm$ 2.1 $\times 10^5$	3.0 $\pm$ 4.7 $\times 10^5$
5. Percent halophilic bacteria	Summer	6.9 $\pm$ 4.7	13.7 $\pm$ 17.9
	Fall	11.7 $\pm$ 9.0	7.4 $\pm$ 1.9
	Winter	31.4 $\pm$ 16.3	38.7 $\pm$ 49.9
	Spring	6.5 $\pm$ 7.2	16.9 $\pm$ 38.0
6. Photosynthetic bacteria (see text)			

a significant ( $P < .05$ ) difference between sites during fall-winter with highest percentages at the Weeks Island site.

The total aerobic heterotrophic, hydrocarbon degrading, and percent hydrocarbon degrading bacteria of the two study sites are comparable to those of other offshore regions (Table 4).

Halophilic bacteria were enumerated in all but two of the 104 sediment samples collected during the study. Populations ranged from  $4.9 \times 10^4$  to  $4.1 \times 10^6$ /ml at the West Hackberry site, and from  $8.0 \times 10^2$  to  $4.7 \times 10^6$ /ml at the Weeks Island site (Appendix Table 8). Analysis of variance indicated a significant ( $P < .01$ ) seasonal difference in halophilic bacterial populations at both sites with highest numbers during summer and lowest during winter (Table 3). There was a significant ( $P < .01$ ) difference between sites during summer, fall, and winter with highest populations at the West Hackberry site. During spring, there was no significant difference between sites.

The percent halophilic bacteria of sediment ranged from 1.1 to 76.6% at the West Hackberry site, and from  $<0.01$  to 200.0% at the Weeks Island site (Appendix Table 9). Analysis of variance demonstrated a significant ( $P < .01$ ) seasonal variation in the percent halophilic bacteria at the West Hackberry site with highest percentages during winter and lowest during spring-summer (Table 3). On the contrary, there was no significant seasonal variation at the Weeks Island site. There was no significant difference between sites in the percent halophilic bacteria.

Photosynthetic bacteria were isolated during fall from only one of 26 stations. During winter, photosynthetic bacteria were cultured from four of the 13 West Hackberry site stations, and from one of the 13 Weeks Island site stations. These bacteria were isolated from six and two of the West Hackberry and Weeks Island site stations during spring, respec-

TABLE 4

Benthic bacterial populations of the two study sites compared to those of other offshore regions.

<u>Offshore Region</u>	<u>Bacterial Type</u>	<u>Range</u>	<u>Source</u>
Louisiana (West Hackberry)	Total aerobic heterotrophic (1)	$1.2 \times 10^5 - 6.4 \times 10^7 / \text{ml}$	Present study
	Hydrocarbon degrading (2)	$3.0 \times 10^2 - 2.0 \times 10^5 / \text{ml}$	
	Percent hydrocarbon degrading (3)	0.04 - 21.3	
Louisiana (Weeks Island)	1	$2.0 \times 10^3 - 1.5 \times 10^7 / \text{ml}$	Present study
	2	$6.0 \times 10^2 - 8.9 \times 10^5 / \text{ml}$	
	3	0.07 - 106.5	
South Texas	1	$4.6 \times 10^4 - 1.3 \times 10^6 / \text{ml}$	Schwarz <u>et al.</u> , 1979
	2	$8.0 \times 10^1 - 1.1 \times 10^5 / \text{ml}$	
	3	0.10 - 20.7	
South Atlantic (South Carolina, Georgia, Florida)	1	$1.0 \times 10^1 - 4.9 \times 10^6 / \text{g}$	Oppenheimer, 1978
	2	$0 - 1.2 \times 10^6 / \text{g}$	
	3	0.0004 - 96	
Alaska (Beaufort Sea)	1	*NR	Roubal and Atlas, 1978
	2	$0.1 - 8.7 \times 10^3 / \text{g}$	
	3	*NR	
North Sea	1	$9.6 \times 10^3 - 3.9 \times 10^7 / \text{ml}$	Gunkel, 1973
	2	$5.7 \times 10^1 - 2.3 \times 10^6 / \text{ml}$	
	3	*NR	

\*NR - Not Reported

tively. Photosynthetic bacterial populations never exceeded 10/ml wet sediment.

Aerobic heterotrophic bacteria of water ranged from  $2.6 \times 10^2$  to  $2.1 \times 10^4$ /ml at the West Hackberry site, and from  $1.0 \times 10^2$  to  $1.4 \times 10^4$ /ml at the Weeks Island site (Appendix Table 13). Analysis of variance indicated a significant ( $P < .01$ ) seasonal variation in water bacterial populations at both sites with highest numbers during winter and lowest during fall (Table 5). There was no significant difference between sites during summer. There was, however, significantly ( $P < .05$ ) higher populations at the West Hackberry site during fall and winter. During spring, the Weeks Island site had significantly ( $P < .05$ ) higher populations.

#### Predominant bacterial genera

A total of 402 aerobic heterotrophic bacterial isolates were picked from Marine Agar 2216 plates inoculated with sediment dilutions. Of this number, 243 were identified. The remaining isolates lost viability prior to the completion of tests for identification. Substantial loss of isolates prior to identification is a common occurrence, since many bacteria grow initially only because essential nutrients have been added to the medium in the sample inoculum. Bacillus sp. were the predominant aerobic heterotrophic bacteria isolated and identified from West Hackberry site sediment (Table 6). Species of Vibrio and Pseudomonas were also frequently isolated from this site. The predominant aerobic heterotrophic bacteria isolated from Weeks Island site sediment were Vibrio sp. Species of Pseudomonas and Bacillus were also frequently isolated from this site. Members of Enterobacteriaceae, Acinetobacter, Flavobacterium, and the coryneforms were isolated on occasion from the two sites.

A total of 442 bacterial isolates were obtained from growth in positive MPN oil tubes. Of these, 51 exhibited growth when re-inoculated

TABLE 5

Bacterial populations of water from the two study sites during 1978-1979. Each tabulated value represents the mean  $\pm$  1 standard deviation of 13 stations.

<u>Type</u>	<u>Season</u>	<u>Site</u>	
		<u>West Hackberry</u>	<u>Weeks Island</u>
1. Aerobic heterotrophic bacteria (number/ml)	Summer	$3.5 \pm 4.3 \times 10^3$	$4.1 \pm 4.9 \times 10^3$
	Fall	$1.6 \pm 3.1 \times 10^3$	$0.2 \pm 0.1 \times 10^3$
	Winter	$10.5 \pm 5.7 \times 10^3$	$4.4 \pm 3.4 \times 10^3$
	Spring	$1.9 \pm 3.6 \times 10^3$	$3.5 \pm 3.3 \times 10^3$

TABLE 6

Predominant bacterial genera of sediment from the two study sites during 1978-1979.

<u>Type</u>	<u>Site</u>	
	<u>West Hackberry</u>	<u>Weeks Island</u>
1. Aerobic heterotrophic bacteria	<u>Bacillus</u> (63)* <u>Vibrio</u> (41) <u>Pseudomonas</u> (23) <u>Enterobacteriaceae</u> (3) <u>Acinetobacter</u> (1) <u>coryneform</u> (1) <u>Flavobacterium</u> (1)	<u>Vibrio</u> (63)* <u>Pseudomonas</u> (23) <u>Bacillus</u> (17) <u>Acinetobacter</u> (5) <u>coryneform</u> (1) <u>Enterobacteriaceae</u> (1)
2. Hydrocarbon degrading bacteria	<u>Pseudomonas</u> (34) <u>Vibrio</u> (1)	<u>Pseudomonas</u> (11) <u>Vibrio</u> (5)
3. Halophilic bacteria	<u>Bacillus</u> (49) <u>Pseudomonas</u> (19) <u>Vibrio</u> (18) <u>coryneforms</u> (2)	<u>Vibrio</u> (46) <u>Bacillus</u> (20) <u>Pseudomonas</u> (8) <u>Flavobacterium</u> (3) <u>coryneform</u> (1) <u>Micrococcus</u> (1)

\* Total number of isolates identified from all stations and seasons.

into fresh oil tubes. The predominant hydrocarbon degrading bacteria from both sites were Pseudomonas sp. (Table 6). The only other hydrocarbon degrading bacteria isolated from the two sites were species of Vibrio.

A total of 253 bacterial isolates were selected from the halophilic medium inoculated with sediment dilutions. Of this number, 167 were identified. The remaining isolates lost viability prior to the completion of tests for identification. Bacillus sp. were the predominant halophilic bacteria isolated from West Hackberry site sediment (Table 6). Species of Pseudomonas and Vibrio were also frequently isolated from this site. The predominant halophilic bacteria isolated from the Weeks Island site were Vibrio sp. Species of Bacillus and Pseudomonas were frequently isolated from Weeks Island site sediment. Also occurring at the two sites were species of Flavobacterium, Micrococcus, and coryneforms.

A total of 529 aerobic heterotrophic bacterial isolates were selected from Marine Agar 2216 plates inoculated with water dilutions. Of this number, 322 were identified. The remaining isolates lost viability prior to the completion of tests for identification. Vibrio sp. were the predominant aerobic heterotrophic bacteria of water from both sites (Table 7). Species of Pseudomonas, Bacillus, Flavobacterium, and Enterobacteriaceae were frequently isolated from both sites. Also occurring in water from the two study sites were species of Staphylococcus, Acinetobacter, coryneforms, and Micrococcus.

#### Bacterial diversity

The bacterial diversity (index 1) of sediment ranged from 0.38 to 1.93 at the West Hackberry site, and from 0.12 to 2.06 at the Weeks Island site (Appendix Table 10). Analysis of variance demonstrated a significant ( $P < .01$ ) seasonal variation in the diversity of benthic bacteria at both sites with highest diversity during summer-fall and lowest during

TABLE 7

Predominant bacterial genera of water from the two study sites during 1978-1979.

<u>Type</u>	<u>Site</u>	
	<u>West Hackberry</u>	<u>Weeks Island</u>
1. Aerobic heterotrophic bacteria	<u>Vibrio</u> (52)* <u>Pseudomonas</u> (47) <u>Bacillus</u> (26) <u>Flavobacterium</u> (11) <u>Enterobacteriaceae</u> (9) <u>Acinetobacter</u> (3) <u>coryneforms</u> (2) <u>Staphylococcus</u> (2)	<u>Vibrio</u> (72)* <u>Pseudomonas</u> (48) <u>Bacillus</u> (15) <u>Enterobacteriaceae</u> (14) <u>Flavobacterium</u> (12) <u>Staphylococcus</u> (5) <u>coryneforms</u> (2) <u>Acinetobacter</u> (1) <u>Micrococcus</u> (1)

\* Total number of isolates identified from all stations and seasons.

TABLE 8

Bacterial diversity\* of sediment and water from the two study sites during 1978-1979. Each tabulated value represents the mean  $\pm$  1 standard deviation of 13 stations.

<u>Substrate</u>	<u>Season</u>	<u>Site</u>	
		<u>West Hackberry</u>	<u>Weeks Island</u>
Sediment	Summer	1.30 $\pm$ 0.43	1.60 $\pm$ 0.43
	Fall	1.37 $\pm$ 0.40	1.24 $\pm$ 0.28
	Winter	1.22 $\pm$ 0.41	1.11 $\pm$ 0.33
	Spring	0.49 $\pm$ 0.13	0.54 $\pm$ 0.21
Water	Summer	0.88 $\pm$ 0.23	1.12 $\pm$ 0.39
	Fall	1.61 $\pm$ 0.34	1.58 $\pm$ 0.42
	Winter	0.58 $\pm$ 0.15	0.43 $\pm$ 0.31
	Spring	0.53 $\pm$ 0.18	0.37 $\pm$ 0.19

\* Determined using Index 1:  $S/\sqrt{N}$ , where S is the number of colony types, and N is the total number of colonies.

winter-spring (Table 8). There was a significant ( $P < .05$ ) difference between sites during summer (highest at Weeks Island) and fall (highest at West Hackberry). During winter and spring, there was no significant difference between sites.

The bacterial diversity (index 1) of water ranged from 0.14 to 2.15 at the West Hackberry site, and from 0.15 to 2.10 at the Weeks Island site (Appendix Table 14). Analysis of variance demonstrated a significant ( $P < .01$ ) seasonal variation in the diversity of water bacteria at both sites, with highest diversity during fall and lowest during spring (Table 8). There was a significant ( $P < .01$ ) difference between sites during summer, winter, and spring. Bacterial diversity during the summer was greatest at the Weeks Island site. However, during winter and spring, the West Hackberry site had the greatest diversity. There was no significant difference between sites during fall.

#### Heterotrophic activity

In 86 of the 104 sediment samples collected during the study, the mean uptake rate of  $^{14}\text{C}$ -(U) glucose was greater than the mean mineralization rate (Appendix Tables 11 and 12, respectively). Likewise, the mean rate of  $^{14}\text{C}$ -(U) glucose uptake by water was greater than the mean mineralization rate in 76 of the 104 samples collected during the study (Appendix Tables 15 and 16, respectively). Therefore, the majority of  $^{14}\text{C}$ -(U) glucose utilized by bacteria during the 1 to 3 hour incubation period was taken into cells. For this reason, the uptake rate of  $^{14}\text{C}$ -(U) glucose was selected to represent the heterotrophic activity of sediment and water collected during the study.

The mean rate of  $^{14}\text{C}$ -(U) glucose uptake by sediment bacteria ranged from 0 to  $1784 \times 10^2$  dpm/ml/hr at the West Hackberry site, and from 0 to  $834 \times 10^2$  dpm/ml/hr at the Weeks Island site (Appendix Table 11). Analysis of

variance demonstrated a significant ( $P < .05$ ) seasonal difference in the uptake rate of  $^{14}\text{C}$ -(U) glucose by benthic bacteria at both sites with highest uptake rates during summer and lowest during winter-spring (Table 9). Mean uptake rates were greatest at the West Hackberry site during all seasons. However, these differences were significant ( $P < .05$ ) only during winter.

The mean rate of  $^{14}\text{C}$ -(U) glucose uptake by water bacteria ranged from 0 to 69.3 dpm/ml/hr at the West Hackberry site, and from 0 to 403.7 dpm/ml/hr at the Weeks Island site (Appendix Table 15). Analysis of variance demonstrated no significant seasonal variation in the uptake rate of  $^{14}\text{C}$ -(U) glucose by water bacteria from the two sites (Table 9). There was a significant ( $P < .01$ ) difference between sites during three of the four seasons. Greatest uptake rates occurred at the West Hackberry site during summer and fall. During spring, uptake rates were greatest at the Weeks Island site. There was no significant difference between sites during winter.

### CONCLUSIONS

Aerobic heterotrophic bacteria in sediment from the two study sites exhibited significant seasonal variations with highest levels during summer and lowest during winter. Similar seasonal patterns have been reported by Oppenheimer (1978) and Schwarz et al. (1979a). Seasonal fluctuations in benthic bacterial populations are likely related to changes in one or more environmental parameters. Temperature may be one such factor. Mean sediment temperatures at the two study sites varied from a high of  $28^{\circ}\text{C}$  during summer to a low of  $10$ - $12^{\circ}\text{C}$  during winter (Table 1). Temperature regulates rates of organic carbon utilization and growth in bacteria (Stanier et al., 1970). Therefore, the seasonal fluctuations in temperature recorded at the two study sites likely

TABLE 9

Heterotrophic activity (dpm of  $^{14}\text{C}$ -(U) glucose uptake/ml/hr) of sediment and water from the two study sites during 1978-1979. Each tabulated value represents the mean  $\pm$  1 standard deviation of 13 stations.

<u>Substrate</u>	<u>Season</u>	<u>Site</u>	
		<u>West Hackberry</u>	<u>Weeks Island</u>
Sediment ( $\times 10^2$ )	Summer	548.1 $\pm$ 468.8	385.4 $\pm$ 341.0
	Fall	334.6 $\pm$ 754.6	147.2 $\pm$ 40.8
	Winter	217.9 $\pm$ 300.5	60.6 $\pm$ 205.9
	Spring	209.2 $\pm$ 492.0	97.9 $\pm$ 246.2
Water	Summer	10.3 $\pm$ 16.9	2.8 $\pm$ 4.3
	Fall	9.2 $\pm$ 16.4	0.1 $\pm$ 0.3
	Winter	9.2 $\pm$ 20.4	9.1 $\pm$ 42.2
	Spring	8.7 $\pm$ 33.9	112.5 $\pm$ 231.0

contribute to the observed seasonal distribution of benthic bacteria by increasing rates of organic carbon utilization and growth during summer and slowing these rates during winter. Seasonal variations in benthic populations may also be related to fluctuations in other environmental factors, such as rates of organic input to the sediments (Schwarz et al., 1979a).

Bacterial populations of marine sediments are related to the texture of the substrate more than any other environmental parameter (Zobell, 1946). Fine textured sediments contain higher bacterial populations than coarse textured sediments, a fact attributed to the higher organic content of the former substrate. In the present study, sediment populations of aerobic heterotrophic bacteria were greatest at the West Hackberry site during each of the four seasons. Hausknecht (1979) reported that the West Hackberry site sediment is finer textured (<40% sand) than the Weeks Island site sediment (>70% sand) and contains approximately twice the organic content of the Weeks Island site sediment. Therefore, the higher sediment populations at the West Hackberry site are probably due to the finer nature of the sediments and to their higher organic content.

Aerobic heterotrophic bacteria of water from the two study sites also exhibited significant seasonal variations with highest populations during winter and lowest during fall. This seasonal pattern is unlike that observed for sediment populations and is not directly related to seasonal fluctuations in temperature (Table 1) or to expected seasonal fluctuations in organic production (Kamykowski and van Baalen, 1979). Maximum population levels during winter suggest that the distribution of bacteria in water is determined largely by mixing processes that resuspend particles. The two study sites are located in shallow waters (<13m) subject to wind-induced mixing processes. Winds and

mixing processes are expected to be maximal during winter, resulting in a greater resuspension of particles during this time. Suspended particles in coastal waters contain an attached microbial population (Seki, 1970). Therefore, a higher concentration of particles suspended in the water during winter would result in higher bacterial populations at this time.

Microorganisms capable of degrading hydrocarbons are widely distributed in water and sediments (Zobell, 1973). Sediment from the two study sites likewise contained a resident bacterial population capable of degrading hydrocarbons. These populations exhibited significant seasonal variations with highest numbers during summer-fall and lowest during winter-spring. Similar seasonal trends in hydrocarbon degrading bacteria have been observed by Roubal and Atlas (1978) and by Schwarz et al. (1979a). The seasonality of hydrocarbon degrading bacteria observed in this and other studies is likely related to seasonal fluctuations in environmental parameters. The activity of hydrocarbon degrading bacteria is affected by oxygen, temperature, organic matter, concentration of oil, and bacterial predators (Zobell, 1973). Seasonal variations in one or more of these factors could have resulted in the changes observed for hydrocarbon degrading populations.

Several studies indicate that a high number (Zobell, 1969; Hood et al., 1975) or high percentage (Hood et al., 1975; Walker and Colwell, 1976) of hydrocarbon degrading bacteria are directly related to high levels of hydrocarbons. However, other studies indicate that the number (Walker and Colwell, 1976) and percentage (Hansen et al., 1977) of hydrocarbon degrading bacteria may not be related to hydrocarbons when levels are low. There appears to be, therefore, a "threshold" level of hydrocarbons that must be present in the environment to elicit a response

from hydrocarbon degrading bacteria. Below this level, there may be no correlation between the two. In the present study, there appears to be no relation between levels of hydrocarbons in sediments and populations of hydrocarbon degrading bacteria. For example, highest hydrocarbon levels were found at the West Hackberry site during summer and fall (Boehm, 1979). However, the number and percent hydrocarbon degrading bacteria of sediment were not significantly higher at this site during these seasons. Apparently, concentrations of hydrocarbons at the West Hackberry site, although higher than those at the Weeks Island site, are not high enough to significantly stimulate hydrocarbon degrading populations.

Sediment from the two study sites contained a resident population of halophilic bacteria that exhibited seasonal and spatial variations similar to those of the aerobic heterotrophic population. The percent halophilic bacteria in the total population averaged 6% at the West Hackberry site and 8% at the Weeks Island site. The highest mean salinity of mid-depth water from the two study sites was 30 o/oo (Table 2). The salinity of the halophilic culture medium was 50 o/oo. Therefore, a salinity increase of  $\geq 20$  o/oo above mean in situ levels may effect the growth of the majority of benthic bacteria present at the two study sites. However, the area experiencing a salinity increase of this magnitude would be relatively small, since a salinity increase of only 1 o/oo above in situ levels is expected at a distance of 3000 m from the brine diffuser (Stolzenbach, personal communication).

Photosynthetic bacteria of sediment from the two study sites were neither widely distributed nor abundant, being isolated only occasionally in numbers never exceeding 10/ml wet sediment. The low incidence and levels of these bacteria suggest that the sediment environment of the

two study sites is not well suited for their growth. Photosynthetic bacteria (purple and green sulfur) occur in anaerobic and sulfide-containing environments where sufficient sunlight for growth can penetrate (Sieburth, 1979). Sufficient sunlight may not penetrate to the sediment surface at the two study sites because of mixing processes that resuspend particles. In addition, it is unlikely that anaerobic conditions develop at or near the sediment surface in these shallow, well-mixed offshore waters. Levels of oxygen measured in South Texas offshore waters (including near-bottom) were never less than 2.90 ml/l (Sackett and Brooks, 1979).

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# APPENDIX A

## SAMPLE AND DATA TABULATIONS

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Appendix Table 1

Station characteristics for samples collected during the summer cruise, 1978.

<u>Site/ Station</u>	<u>Time</u>	<u>Day (June)</u>	<u>Temperature (°C)</u>		<u>Mid-depth water Salinity(°/oo)</u>	<u>Water depth(m)</u>
			<u>Sediment</u>	<u>Mid-depth water</u>		
A 2	1030	27	27	29	19	11
A 5	1815	26	28	29	19	11
A 6	1000	26	28	29	22	11
A 7	1115	26	28	29	16	10
A 8	745	27	27	29	22	11
A 9	1530	26	28	30	19	11
A10	845	27	27	29	22	13
A11	1330	26	28	27	16	13
A14	2100	23	28	29	21	11
A16	1930	26	28	29	19	10
A17	1220	26	28	30	16	10
A18	1440	26	27	29	22	11
A19	1650	26	27	29	19	12
B 2	730	28	26	30	18	8
B 5	945	28	28	30	19	10
B 6	1745	28	29	31	13	7
B 7	1200	28	30	30	18	8
B 8	1830	28	28	30	22	8
B 9	1530	28	29	31	22	11
B10	730	29	28	30	24	13
B11	1345	28	28	31	18	8
B14	1200	29	29	28	24	7
B16	1100	28	28	30	16	8
B17	1300	28	29	30	17	8
B18	1430	28	28	30	19	10
B19	1615	28	28	30	24	11

Appendix Table 2

Station characteristics for samples collected during the fall cruise, 1978

Site/ Station	Time	Date	Temperature (°C)		Mid-depth water Salinity(°/oo)	Water depth(m)
			Sediment	Mid-depth water		
A 2	2135	10/12	25	25	28	9
A 5	2005	10/12	26	25	28	9
A 6	1445	10/ 3	28	27	27	7
A 7	1400	10/ 3	28	28	27	8
A 8	1800	10/12	26	26	28	9
A 9	0010	10/13	25	25	28	10
A10	0215	10/13	25	25	28	11
A11	1125	10/ 3	28	28	28	11
A14	0840	10/ 3	27	27	28	11
A16	1930	10/12	25	25	28	8
A17	1310	10/ 3	27	28	28	8
A18	0120	10/13	25	25	28	11
A19	2310	10/12	25	25	28	10
B 2	1215	11/ 9	23	22	30	9
B 5	1355	11/ 9	23	22	31	9
B 6	1620	11/ 9	22	21	28	7
B 7	1535	11/ 9	22	22	28	7
B 8	0715	11/10	23	22	30	9
B 9	0910	11/10	23	23	30	11
B10	0955	11/10	23	23	31	12
B11	1120	11/10	23	23	30	8
B14	1315	11/10	23	23	30	8
B16	1455	11/ 9	23	22	30	7
B17	1725	11/ 9	22	22	28	8
B18	1045	11/10	23	23	30	11
B19	0830	11/10	23	22	30	10

Appendix Table 3

Station characteristics for samples collected during the winter cruise, 1979.

<u>Site/ Station</u>	<u>Time</u>	<u>Date (January)</u>	<u>Temperature (°C)</u>		<u>Mid-depth water Salinity(°/oo)</u>	<u>Water depth(m)</u>
			<u>Sediment</u>	<u>Mid-depth water</u>		
A 2	0810	25	11	9	24	10
A 5	-	25	10	9	20	11
A 6	1630	25	10	9	22	8
A 7	1525	25	10	9	21	9
A 8	1915	25	9	9	24	10
A 9	0850	26	11	10	25	11
A10	0940	26	-	11	26	11
A11	1100	26	11	10	25	10
A14	1220	26	11	10	25	10
A16	1430	25	10	9	24	9
A17	1735	25	11	9	20	8
A18	1035	26	-	11	25	11
A19	2125	25	10	10	25	12
B 2	0935	28	11	12	30	9
B 5	0755	28	11	11	23	9
B 6	1500	27	12	11	24	7
B 7	1345	27	12	12	29	7
B 8	1700	27	13	12	28	10
B 9	1910	27	13	12	26	11
B10	2000	27	12	11	25	12
B11	1130	27	11	10	20	8
B14	0840	27	10	10	18	7
B16	1610	27	11	11	22	7
B17	1255	27	12	11	26	7
B18	1750	27	-	13	32	11
B19	0715	28	13	11	22	10

Appendix Table 4

Station characteristics for samples collected during the spring cruise, 1979.

Site/ Station	Time	Date	Temperature (°C)		Mid-depth water Salinity(°/oo)	Water depth(m)
			Sediment	Mid- depth water		
A 2	0630	5/ 2	22	23	18	11
A 5	0850	5/ 2	22	23	18	11
A 6	1930	5/ 1	22	23	16	9
A 7	1850	5/ 1	-	23	18	10
A 8	1025	5/ 2	23	24	20	11
A 9	1121	5/ 2	23	23	19	12
A10	1150	5/ 2	23	23	22	11
A11	1543	5/ 1	22	23	20	11
A14	1430	5/ 1	23	23	20	10
A16	2000	5/ 1	22	23	18	11
A17	1830	5/ 1	22	23	18	11
A18	1230	5/ 2	23	23	18	12
A19	0922	5/ 2	23	23	19	11
B 2	2105	4/30	22	22	18	9
B 5	2000	4/30	22	22	18	8
B 6	1346	4/30	23	23	18	6
B 7	1200	4/30	22	22	18	7
B 8	1520	4/30	23	23	18	9
B 9	1630	4/30	23	23	18	10
B10	1730	4/30	23	22	19	12
B11	1011	4/30	22	22	18	8
B14	0743	4/30	22	22	18	7
B16	1425	4/30	23	23	18	7
B17	1130	4/30	22	22	18	8
B18	1605	4/30	23	23	18	10
B19	1925	4/30	-	22	18	10

Appendix Table 5

Total aerobic heterotrophic bacteria of sediment from the two study sites during 1978-1979. Values are mean  $\pm$  1 standard deviation.

SITE/ STATION	TOTAL AEROBIC HETEROTROPHIC BACTERIA/ml WET SEDIMENT ( $\times 10^5$ )			
	SUMMER	FALL	WINTER	SPRING
A 2	9.1 $\pm$ 1.7	107.3 $\pm$ 16.0	5.3 $\pm$ 5.5	110.8 $\pm$ 9.5
A 5	101.2 $\pm$ 24.6	87.2 $\pm$ 15.8	1.2 $\pm$ 0.5	113.7 $\pm$ 19.3
A 6	157.2 $\pm$ 44.6	104.5 $\pm$ 22.7	6.3 $\pm$ 3.1	15.5 $\pm$ 3.5
A 7	30.6 $\pm$ 7.4	46.0 $\pm$ 9.3	3.9 $\pm$ 0.5	187.5 $\pm$ 82.9
A 8	360.0 $\pm$ 75.9	103.5 $\pm$ 18.7	5.7 $\pm$ 2.0	122.3 $\pm$ 45.6
A 9	683.3 $\pm$ 336.8	60.8 $\pm$ 27.7	4.3 $\pm$ 0.2	126.0 $\pm$ 24.8
A10	80.2 $\pm$ 18.9	93.8 $\pm$ 8.7	10.5 $\pm$ 1.6	91.3 $\pm$ 14.8
A11	314.2 $\pm$ 129.9	97.7 $\pm$ 12.6	1.5 $\pm$ 0.4	91.7 $\pm$ 20.0
A14	285.5 $\pm$ 62.7	35.1 $\pm$ 13.5	1.6 $\pm$ 0.7	134.2 $\pm$ 33.9
A16	628.3 $\pm$ 290.1	56.8 $\pm$ 8.0	3.3 $\pm$ 0.4	139.3 $\pm$ 54.7
A17	591.7 $\pm$ 92.4	63.2 $\pm$ 13.5	3.0 $\pm$ 0.7	143.8 $\pm$ 46.3
A18	72.0 $\pm$ 20.8	66.8 $\pm$ 11.8	3.4 $\pm$ 0.4	162.3 $\pm$ 36.8
A19	70.8 $\pm$ 28.3	51.2 $\pm$ 37.7	8.6 $\pm$ 1.3	136.0 $\pm$ 29.4
B 2	49.0 $\pm$ 14.6	17.0 $\pm$ 3.7	1.1 $\pm$ 0.7	146.3 $\pm$ 34.8
B 5	19.3 $\pm$ 2.4	5.3 $\pm$ 1.1	0.02 $\pm$ 0.04	10.5 $\pm$ 3.6
B 6	18.2 $\pm$ 5.4	9.9 $\pm$ 1.4	2.5 $\pm$ 0.7	11.7 $\pm$ 3.2
B 7	95.3 $\pm$ 19.4	9.2 $\pm$ 1.3	0.15 $\pm$ 0.15	11.7 $\pm$ 1.3
B 8	85.0 $\pm$ 42.9	8.3 $\pm$ 1.6	0.4 $\pm$ 0.3	13.5 $\pm$ 2.2
B 9	58.5 $\pm$ 7.3	10.3 $\pm$ 2.4	3.9 $\pm$ 1.1	127.3 $\pm$ 19.9
B10	8.9 $\pm$ 3.6	19.3 $\pm$ 1.4	0.1 $\pm$ 0.1	144.2 $\pm$ 35.7
B11	138.8 $\pm$ 50.5	11.6 $\pm$ 2.5	0.4 $\pm$ 0.2	9.4 $\pm$ 1.1
B14	21.9 $\pm$ 5.9	125.5 $\pm$ 15.1	0.5 $\pm$ 0.2	5.9 $\pm$ 1.3
B16	90.0 $\pm$ 6.0	8.8 $\pm$ 1.5	0.2 $\pm$ 0.2	9.6 $\pm$ 1.8
B17	76.2 $\pm$ 14.5	8.5 $\pm$ 0.8	0.2 $\pm$ 0.1	1.1 $\pm$ 2.0
B18	17.4 $\pm$ 4.3	11.4 $\pm$ 4.5	0.2 $\pm$ 0.1	1463.3 $\pm$ 274.9
B19	12.3 $\pm$ 2.0	11.3 $\pm$ 0.8	0.4 $\pm$ 0.2	43.0 $\pm$ 9.7

Appendix Table 6

Number of hydrocarbon degrading bacteria of sediment from the two study sites during 1978-1979. Values are mean  $\pm$  1 standard deviation.

SITE/ STATION	NUMBER OF HYDROCARBON DEGRADING BACTERIA/ml WET SEDIMENT ( $\times 10^3$ )			
	SUMMER	FALL	WINTER	SPRING
A 2	1.4 $\pm$ 0.6	39.0 $\pm$ 31.2	4.6 $\pm$ 4.0	24.7 $\pm$ 18.5
A 5	11.2 $\pm$ 3.3	67.3 $\pm$ 36.9	0.3 $\pm$ 0.2	76.3 $\pm$ 28.9
A 6	67.3 $\pm$ 36.9	156.7 $\pm$ 50.3	19.7 $\pm$ 22.9	47.0 $\pm$ 39.8
A 7	3.5 $\pm$ 1.3	27.3 $\pm$ 16.4	1.6 $\pm$ 0.7	70.3 $\pm$ 25.3
A 8	102.0 $\pm$ 52.5	102.0 $\pm$ 52.5	121.7 $\pm$ 112.9	81.0 $\pm$ 10.4
A 8	28.7 $\pm$ 17.0	88.7 $\pm$ 36.9	19.2 $\pm$ 23.5	61.7 $\pm$ 76.5
A10	67.3 $\pm$ 36.9	102.0 $\pm$ 52.5	30.3 $\pm$ 13.6	48.4 $\pm$ 42.1
A11	11.9 $\pm$ 11.1	54.0 $\pm$ 48.5	5.3 $\pm$ 3.6	5.4 $\pm$ 1.8
A14	54.5 $\pm$ 51.8	67.3 $\pm$ 36.9	26.4 $\pm$ 18.5	18.3 $\pm$ 9.8
A16	205.3 $\pm$ 229.9	83.0 $\pm$ 63.4	3.0 $\pm$ 1.2	60.7 $\pm$ 28.0
A17	166.7 $\pm$ 66.6	199.3 $\pm$ 229.4	11.9 $\pm$ 10.6	59.7 $\pm$ 28.9
A18	3.4 $\pm$ 1.6	80.7 $\pm$ 60.0	19.1 $\pm$ 8.5	12.4 $\pm$ 9.1
A19	77.1 $\pm$ 115.1	8.5 $\pm$ 3.9	57.0 $\pm$ 48.4	43.0 $\pm$ 43.4
B 2	404.3 $\pm$ 604.9	23.8 $\pm$ 21.0	49.7 $\pm$ 52.4	64.7 $\pm$ 48.8
B 5	198.0 $\pm$ 230.9	13.6 $\pm$ 9.0	2.1 $\pm$ 0.1	4.0 $\pm$ 4.7
B 6	29.0 $\pm$ 14.7	14.5 $\pm$ 6.8	60.0 $\pm$ 44.7	3.7 $\pm$ 0.8
B 7	164.4 $\pm$ 256.1	240.0 $\pm$ 191.6	5.3 $\pm$ 3.6	9.5 $\pm$ 5.3
B 8	103.3 $\pm$ 118.9	49.7 $\pm$ 52.4	1.8 $\pm$ 0.5	7.6 $\pm$ 2.9
B 9	135.0 $\pm$ 113.2	67.3 $\pm$ 36.9	38.7 $\pm$ 12.7	248.7 $\pm$ 207.1
B10	8.7 $\pm$ 1.0	65.0 $\pm$ 39.1	4.0 $\pm$ 3.1	29.0 $\pm$ 14.7
B11	526.7 $\pm$ 496.5	40.2 $\pm$ 46.2	3.1 $\pm$ 2.1	5.3 $\pm$ 3.6
B14	15.1 $\pm$ 5.8	886.7 $\pm$ 369.5	4.0 $\pm$ 4.6	3.3 $\pm$ 1.4
B16	92.0 $\pm$ 40.1	59.1 $\pm$ 44.1	3.5 $\pm$ 1.1	33.7 $\pm$ 16.2
B17	37.7 $\pm$ 14.4	108.3 $\pm$ 114.1	0.8 $\pm$ 0.6	<1
B18	86.5 $\pm$ 132.9	47.8 $\pm$ 44.4	1.7 $\pm$ 2.3	441.7 $\pm$ 571.4
B19	432.0 $\pm$ 580.8	29.0 $\pm$ 14.7	0.6 $\pm$ 0.5	2.8 $\pm$ 1.3

Appendix Table 7

Percent hydrocarbon degrading bacteria of sediment from the two study sites during 1978-1979.

<u>Site/ Station</u>	<u>Percent hydrocarbon degrading bacteria</u>			
	<u>Summer</u>	<u>Fall</u>	<u>Winter</u>	<u>Spring</u>
A 2	0.15	0.36	0.88	0.22
A 5	0.11	0.77	0.22	0.67
A 6	0.43	1.50	3.12	3.03
A 7	0.11	0.59	0.40	0.37
A 8	0.28	0.99	21.27	0.66
A 9	0.04	1.46	4.49	0.50
A10	0.84	1.09	2.88	0.53
A11	0.04	0.55	3.49	0.06
A14	0.19	1.91	16.31	0.14
A16	0.33	1.46	0.89	0.44
A17	0.28	3.15	3.91	0.42
A18	0.05	1.21	5.65	0.08
A19	1.09	0.17	6.63	0.32
B 2	8.25	1.40	45.99	0.44
B 5	10.26	2.57	106.50	0.38
B 6	1.47	1.46	24.19	0.32
B 7	1.73	26.09	35.33	0.81
B 8	1.22	5.99	4.66	0.56
B 9	2.31	6.53	9.84	1.95
B10	0.98	3.37	30.54	0.20
B11	3.79	3.47	7.75	0.56
B14	0.69	7.07	8.00	0.56
B16	1.02	6.70	15.91	3.51
B17	0.49	12.71	4.15	<0.91
B18	4.97	4.19	10.18	0.30
B19	35.12	2.57	1.43	0.07

Appendix Table 8

Number of halophilic bacteria of sediment from the two study sites during 1978-1979. Values are mean  $\pm$  1 standard deviation.

SITE/ STATION	NUMBER OF HALOPHILIC BACTERIA/ml WET SEDIMENT ( $\times 10^4$ )			
	SUMMER	FALL	WINTER	SPRING
A 2	8.7 $\pm$ 1.0	79.7 $\pm$ 12.6	6.2 $\pm$ 1.2	45.0 $\pm$ 12.7
A 5	57.8 $\pm$ 9.8	132.3 $\pm$ 123.0	5.0 $\pm$ 0.7	61.0 $\pm$ 13.2
A 6	107.5 $\pm$ 14.1	118.2 $\pm$ 17.0	48.5 $\pm$ 13.5	47.0 $\pm$ 6.9
A 7	63.3 $\pm$ 13.4	62.2 $\pm$ 20.5	14.8 $\pm$ 2.7	71.0 $\pm$ 22.9
A 8	122.2 $\pm$ 17.8	84.3 $\pm$ 12.7	12.6 $\pm$ 2.3	69.2 $\pm$ 16.4
A 9	68.5 $\pm$ 15.0	54.8 $\pm$ 24.0	11.6 $\pm$ 1.8	66.5 $\pm$ 15.4
A10	50.3 $\pm$ 7.4	54.7 $\pm$ 6.2	17.2 $\pm$ 4.8	21.0 $\pm$ 5.3
A11	123.8 $\pm$ 16.3	88.8 $\pm$ 24.7	4.9 $\pm$ 0.9	50.5 $\pm$ 15.8
A14	151.2 $\pm$ 54.0	15.1 $\pm$ 2.9	5.4 $\pm$ 0.2	58.7 $\pm$ 24.3
A16	310.3 $\pm$ 140.4	53.2 $\pm$ 9.8	8.5 $\pm$ 1.4	60.8 $\pm$ 17.8
A17	413.3 $\pm$ 90.7	68.0 $\pm$ 6.4	12.4 $\pm$ 1.8	58.2 $\pm$ 24.7
A18	58.2 $\pm$ 24.6	52.5 $\pm$ 8.1	7.0 $\pm$ 1.0	73.3 $\pm$ 13.5
A19	47.5 $\pm$ 11.5	205.3 $\pm$ 256.8	20.3 $\pm$ 6.2	64.5 $\pm$ 29.3
B 2	23.6 $\pm$ 8.0	10.8 $\pm$ 3.2	2.7 $\pm$ 1.1	<0.1
B 5	56.8 $\pm$ 10.2	2.9 $\pm$ 1.1	0.4 $\pm$ 0.2	149.7 $\pm$ 45.5
B 6	13.8 $\pm$ 3.7	9.4 $\pm$ 1.9	6.6 $\pm$ 0.8	13.5 $\pm$ 3.0
B 7	57.7 $\pm$ 7.1	10.0 $\pm$ 2.3	0.2 $\pm$ 0.1	15.6 $\pm$ 2.9
B 8	35.6 $\pm$ 16.6	7.2 $\pm$ 1.9	0.9 $\pm$ 0.4	14.2 $\pm$ 3.8
B 9	29.4 $\pm$ 10.1	7.2 $\pm$ 3.7	5.7 $\pm$ 1.8	96.5 $\pm$ 17.0
B10	6.3 $\pm$ 1.6	8.7 $\pm$ 0.5	0.3 $\pm$ 0.2	40.0 $\pm$ 6.2
B11	102.7 $\pm$ 12.7	7.6 $\pm$ 2.6	1.2 $\pm$ 0.3	6.6 $\pm$ 2.1
B14	147.2 $\pm$ 16.6	104.2 $\pm$ 43.5	2.6 $\pm$ 0.7	4.3 $\pm$ 1.4
B16	43.4 $\pm$ 26.4	4.4 $\pm$ 1.9	0.8 $\pm$ 0.1	11.0 $\pm$ 1.8
B17	12.8 $\pm$ 2.7	8.4 $\pm$ 2.1	0.08 $\pm$ 0.08	<0.1
B18	17.7 $\pm$ 2.6	7.4 $\pm$ 0.6	0.2 $\pm$ 0.1	466.7 $\pm$ 103.3
B19	28.2 $\pm$ 15.8	8.4 $\pm$ 2.1	1.5 $\pm$ 0.6	6.8 $\pm$ 2.3

Appendix Table 9

Percent halophilic bacteria of sediment from the two study sites during 1978-1979.

SITE/ STATION	PERCENT HALOPHILIC BACTERIA			
	SUMMER	FALL	WINTER	SPRING
A 2	9.51	7.43	11.78	4.06
A 5	5.71	15.14	40.65	5.36
A 6	6.84	11.29	76.62	30.32
A 7	20.71	13.52	37.76	3.79
A 8	3.39	8.14	22.03	5.66
A 9	1.07	9.01	27.03	5.28
A10	6.27	5.83	16.33	2.30
A11	3.94	9.09	32.11	5.51
A14	5.30	4.30	33.46	4.37
A16	4.94	9.37	25.44	4.36
A17	6.98	10.76	40.72	4.05
A18	8.08	7.86	20.80	4.52
A19	6.71	40.04	23.58	4.74
B 2	4.82	6.35	25.46	<0.01
B 5	29.43	5.47	200.00	142.57
B 6	7.00	9.49	26.49	11.54
B 7	6.05	10.87	15.33	13.33
B 8	4.19	8.67	24.47	10.52
B 9	5.03	6.99	14.55	7.58
B10	7.08	4.51	24.62	2.77
B11	7.40	6.55	29.25	7.07
B14	67.21	8.29	51.60	7.32
B16	4.82	5.00	37.27	11.46
B17	1.68	9.88	4.00	<0.91
B18	10.17	6.49	14.71	3.19
B19	22.93	7.43	35.71	1.58

Appendix Table 10

Bacterial diversity index of sediment from the two study sites during 1978-1979. Values are mean  $\pm$  1 standard deviation.

SITE/ STATION	BACTERIAL DIVERSITY INDEX							
	SUMMER		FALL		WINTER		SPRING	
	Index 1	Index 2	Index 1	Index 2	Index 1	Index 2	Index 1	Index 2
A 2	1.54 $\pm$ 0.25	6.98 $\pm$ 1.24	1.65 $\pm$ 0.33	7.90 $\pm$ 1.63	1.17 $\pm$ 0.34	3.87 $\pm$ 0.95	0.55 $\pm$ 0.12	2.52 $\pm$ 0.63
A 5	1.17 $\pm$ 0.24	5.33 $\pm$ 1.29	1.20 $\pm$ 0.12	5.25 $\pm$ 0.61	1.36 $\pm$ 0.38	3.34 $\pm$ 1.73	0.48 $\pm$ 0.08	2.01 $\pm$ 0.50
A 6	1.19 $\pm$ 0.07	6.23 $\pm$ 0.86	1.24 $\pm$ 0.25	5.78 $\pm$ 1.45	0.83 $\pm$ 0.12	2.94 $\pm$ 0.53	0.59 $\pm$ 0.07	2.89 $\pm$ 0.41
A 7	0.90 $\pm$ 0.09	5.86 $\pm$ 0.51	1.93 $\pm$ 0.19	7.24 $\pm$ 0.81	1.04 $\pm$ 0.24	3.46 $\pm$ 0.94	0.38 $\pm$ 0.08	1.86 $\pm$ 0.25
A 8	1.68 $\pm$ 0.16	5.80 $\pm$ 0.67	1.52 $\pm$ 0.26	7.27 $\pm$ 1.50	1.39 $\pm$ 0.42	5.21 $\pm$ 0.93	0.43 $\pm$ 0.09	1.83 $\pm$ 0.62
A 9	0.91 $\pm$ 0.36	3.29 $\pm$ 1.16	1.01 $\pm$ 0.24	3.85 $\pm$ 1.23	1.23 $\pm$ 0.16	4.30 $\pm$ 0.59	0.46 $\pm$ 0.12	1.99 $\pm$ 0.64
A10	1.39 $\pm$ 0.29	5.92 $\pm$ 1.07	1.33 $\pm$ 0.21	6.17 $\pm$ 0.93	0.74 $\pm$ 0.12	3.23 $\pm$ 0.54	0.52 $\pm$ 0.20	2.04 $\pm$ 0.93
A11	0.90 $\pm$ 0.25	3.83 $\pm$ 0.98	1.51 $\pm$ 0.28	6.97 $\pm$ 1.33	1.88 $\pm$ 0.35	5.32 $\pm$ 1.03	0.56 $\pm$ 0.11	2.21 $\pm$ 0.51
A14	0.63 $\pm$ 0.07	3.94 $\pm$ 0.57	0.96 $\pm$ 0.17	6.48 $\pm$ 0.93	1.63 $\pm$ 0.37	3.53 $\pm$ 1.08	0.46 $\pm$ 0.10	2.05 $\pm$ 0.48
A16	1.51 $\pm$ 0.33	5.89 $\pm$ 1.20	1.53 $\pm$ 0.27	6.00 $\pm$ 1.15	1.10 $\pm$ 0.13	3.51 $\pm$ 0.39	0.53 $\pm$ 0.15	2.38 $\pm$ 0.61
A17	1.82 $\pm$ 0.18	7.33 $\pm$ 1.04	1.71 $\pm$ 0.26	6.93 $\pm$ 1.28	1.01 $\pm$ 0.21	3.06 $\pm$ 0.71	0.53 $\pm$ 0.11	2.41 $\pm$ 0.45
A18	1.74 $\pm$ 0.16	7.38 $\pm$ 0.95	1.50 $\pm$ 0.23	6.15 $\pm$ 0.87	1.61 $\pm$ 0.18	5.45 $\pm$ 0.70	0.39 $\pm$ 0.10	1.81 $\pm$ 0.51
A19	1.59 $\pm$ 0.35	6.51 $\pm$ 1.26	0.71 $\pm$ 0.33	4.78 $\pm$ 1.72	0.90 $\pm$ 0.17	3.79 $\pm$ 0.91	0.40 $\pm$ 0.14	1.74 $\pm$ 0.64
B 2	1.86 $\pm$ 0.24	7.10 $\pm$ 1.39	0.68 $\pm$ 0.16	3.51 $\pm$ 1.05	1.18 $\pm$ 0.33	2.72 $\pm$ 0.81	0.48 $\pm$ 0.07	2.22 $\pm$ 0.47
B 5	1.09 $\pm$ 0.48	6.24 $\pm$ 2.75	1.62 $\pm$ 0.27	6.21 $\pm$ 1.07	1.00 $\pm$ 0.00	0 $\pm$ 0	0.70 $\pm$ 0.19	3.01 $\pm$ 0.65
B 6	1.45 $\pm$ 0.25	8.05 $\pm$ 0.95	1.19 $\pm$ 0.128	5.43 $\pm$ 1.47	0.75 $\pm$ 0.16	1.94 $\pm$ 0.51	0.66 $\pm$ 0.09	2.98 $\pm$ 0.54
B 7	1.85 $\pm$ 0.30	8.55 $\pm$ 1.19	1.33 $\pm$ 0.22	5.96 $\pm$ 0.88	1.16 $\pm$ 0.37	1.66 $\pm$ 1.92	0.47 $\pm$ 0.16	2.01 $\pm$ 0.82
B 8	1.75 $\pm$ 0.36	7.76 $\pm$ 2.47	1.40 $\pm$ 0.16	6.10 $\pm$ 0.72	1.52 $\pm$ 0.56	3.13 $\pm$ 2.28	0.55 $\pm$ 0.11	2.56 $\pm$ 0.71
B 9	1.87 $\pm$ 0.42	7.48 $\pm$ 1.69	1.33 $\pm$ 0.18	6.16 $\pm$ 0.75	1.15 $\pm$ 0.13	3.87 $\pm$ 0.68	0.55 $\pm$ 0.04	2.53 $\pm$ 0.21
B10	2.15 $\pm$ 0.48	9.66 $\pm$ 1.83	1.15 $\pm$ 0.08	6.56 $\pm$ 0.57	1.11 $\pm$ 0.18	1.08 $\pm$ 1.55	0.52 $\pm$ 0.10	2.46 $\pm$ 0.71
B11	1.49 $\pm$ 0.28	7.66 $\pm$ 1.62	1.35 $\pm$ 0.19	6.49 $\pm$ 0.74	1.17 $\pm$ 0.28	1.78 $\pm$ 1.18	0.71 $\pm$ 0.11	3.02 $\pm$ 0.66
B14	0.91 $\pm$ 0.26	5.19 $\pm$ 1.28	1.03 $\pm$ 0.11	5.01 $\pm$ 0.61	0.89 $\pm$ 0.18	1.38 $\pm$ 0.74	0.83 $\pm$ 0.13	3.02 $\pm$ 0.47
B16	1.46 $\pm$ 0.25	6.57 $\pm$ 1.18	1.19 $\pm$ 0.09	5.23 $\pm$ 0.61	1.08 $\pm$ 0.18	1.14 $\pm$ 1.39	0.54 $\pm$ 0.08	2.19 $\pm$ 0.40
B17	1.75 $\pm$ 0.23	7.46 $\pm$ 1.02	1.25 $\pm$ 0.21	5.45 $\pm$ 1.04	0.97 $\pm$ 0.26	0.83 $\pm$ 1.39	0.39 $\pm$ 0.26	0.19 $\pm$ 0.47
B18	1.54 $\pm$ 0.14	8.65 $\pm$ 0.89	1.24 $\pm$ 0.28	5.71 $\pm$ 1.03	1.02 $\pm$ 0.25	1.00 $\pm$ 1.49	0.12 $\pm$ 0.04	1.21 $\pm$ 0.41
B19	1.71 $\pm$ 0.20	8.56 $\pm$ 0.74	1.39 $\pm$ 0.18	6.59 $\pm$ 0.91	1.39 $\pm$ 0.43	2.74 $\pm$ 1.83	0.51 $\pm$ 0.08	1.43 $\pm$ 0.31

Appendix Table 11

Heterotrophic activity ( $^{14}\text{C}$ -(U) glucose uptake) of bacteria of sediment from the two study sites during 1978-1979. Values are mean  $\pm$  1 standard deviation.

SITE/ STATION	$^{14}\text{C}$ -(U) glucose uptake rate (dpm/ml/hr $\times 10^2$ )			
	SUMMER	FALL	WINTER	SPRING
A 2	173.2 $\pm$ 215.8	100.6 $\pm$ 174.2	-	1142.2 $\pm$ 1678.8
A 5	633.6 $\pm$ 785.2	230.1 $\pm$ 34.7	-	0 $\pm$ 0
A 6	54.9 $\pm$ 49.9	0 $\pm$ 0	10.5 $\pm$ 0.9	302.3 $\pm$ 67.3
A 7	192.3 $\pm$ 333.1	0 $\pm$ 0	8.5 $\pm$ 0.8	96.9 $\pm$ 86.0
A 8	399.8 $\pm$ 79.1	241.8 $\pm$ 163.4	0 $\pm$ 0	41.0 $\pm$ 71.0
A 9	881.2 $\pm$ 325.7	0 $\pm$ 0	324.7 $\pm$ 277.0	181.8 $\pm$ 146.0
A10	281.3 $\pm$ 34.1	1015.3 $\pm$ 1139.0	397.0 $\pm$ 353.0	114.4 $\pm$ 198.1
A11	1470.7 $\pm$ 161.2	1784.0 $\pm$ 1986.1	749.1 $\pm$ 162.4	60.6 $\pm$ 77.8
A14	419.5 $\pm$ 373.1	9.8 $\pm$ 17.0	87.3 $\pm$ 151.2	60.9 $\pm$ 52.9
A16	773.5 $\pm$ 389.2	99.6 $\pm$ 14.3	8.2 $\pm$ 0.8	284.2 $\pm$ 250.5
A17	699.8 $\pm$ 74.6	12.8 $\pm$ 22.1	7.2 $\pm$ 1.6	88.9 $\pm$ 154.0
A18	494.3 $\pm$ 618.7	706.2 $\pm$ 632.9	-	281.4 $\pm$ 22.9
A19	641.1 $\pm$ 318.5	150.2 $\pm$ 49.1	584.1 $\pm$ 105.2	65.8 $\pm$ 113.9
B 2	174.0 $\pm$ 44.2	143.6 $\pm$ 16.1	351.1 $\pm$ 592.8	245.5 $\pm$ 425.2
B 5	544.8 $\pm$ 636.2	110.4 $\pm$ 3.4	1.2 $\pm$ 0.4	10.0 $\pm$ 12.8
B 6	224.5 $\pm$ 58.2	171.3 $\pm$ 18.0	90.0 $\pm$ 103.4	0 $\pm$ 0
B 7	596.9 $\pm$ 210.6	160.3 $\pm$ 10.5	5.1 $\pm$ 2.8	100.3 $\pm$ 173.8
B 8	228.7 $\pm$ 43.3	127.8 $\pm$ 23.5	5.7 $\pm$ 0.8	136.9 $\pm$ 237.1
B 9	585.3 $\pm$ 495.3	86.2 $\pm$ 22.1	0 $\pm$ 0	207.6 $\pm$ 359.6
B10	60.0 $\pm$ 8.3	164.3 $\pm$ 33.1	1.7 $\pm$ 0.4	0 $\pm$ 0
B11	539.1 $\pm$ 336.6	203.4 $\pm$ 9.5	2.0 $\pm$ 1.1	0 $\pm$ 0
B14	389.5 $\pm$ 398.0	122.2 $\pm$ 73.1	329.2 $\pm$ 394.3	7.7 $\pm$ 1.5
B16	833.9 $\pm$ 766.8	104.4 $\pm$ 4.0	0 $\pm$ 0	401.5 $\pm$ 677.9
B17	399.2 $\pm$ 257.7	165.4 $\pm$ 13.9	1.8 $\pm$ 0.5	0 $\pm$ 0
B18	277.3 $\pm$ 56.3	198.0 $\pm$ 19.2	0.5 $\pm$ 0.6	134.2 $\pm$ 117.4
B19	396.1 $\pm$ 307.0	156.7 $\pm$ 10.0	0 $\pm$ 0	29.3 $\pm$ 15.6

Appendix Table 12

Heterotrophic activity ( $^{14}\text{C}$ -(U) glucose mineralization) of bacteria of sediment from the two study sites during 1978-1979. Values are mean  $\pm$  1 standard deviation.

SITE/ STATION	$^{14}\text{C}$ -(U) glucose mineralization rate (dpm/ml/hr $\times 10^2$ )			
	SUMMER	FALL	WINTER	SPRING
A 2	20.9 $\pm$ 28.1	29.9 $\pm$ 2.8	-	10.3 $\pm$ 6.9
A 5	6.3 $\pm$ 4.4	19.2 $\pm$ 3.7	-	24.4 $\pm$ 7.9
A 6	23.8 $\pm$ 13.1	15.7 $\pm$ 7.1	12.6 $\pm$ 18.7	17.7 $\pm$ 0.5
A 7	13.6 $\pm$ 4.1	6.2 $\pm$ 0.6	43.0 $\pm$ 36.6	26.0 $\pm$ 5.8
A 8	0.6 $\pm$ 1.1	16.0 $\pm$ 5.4	18.8 $\pm$ 11.8	68.1 $\pm$ 1.2
A 9	3.7 $\pm$ 2.3	18.5 $\pm$ 4.0	7.9 $\pm$ 3.0	26.2 $\pm$ 9.9
A10	11.5 $\pm$ 6.9	18.2 $\pm$ 9.0	21.2 $\pm$ 3.5	13.9 $\pm$ 1.8
A11	15.1 $\pm$ 1.9	21.2 $\pm$ 12.0	10.1 $\pm$ 5.5	0 $\pm$ 0
A14	11.3 $\pm$ 12.9	11.2 $\pm$ 2.4	0 $\pm$ 0	33.9 $\pm$ 9.7
A16	8.1 $\pm$ 5.5	18.8 $\pm$ 9.2	2.0 $\pm$ 0.2	29.0 $\pm$ 12.2
A17	10.4 $\pm$ 9.2	23.0 $\pm$ 2.9	1.7 $\pm$ 0.6	1.9 $\pm$ 3.2
A18	10.9 $\pm$ 7.0	28.3 $\pm$ 8.7	8.6 $\pm$ 1.3	3.3 $\pm$ 3.6
A19	6.7 $\pm$ 1.8	14.1 $\pm$ 3.1	7.1 $\pm$ 5.2	30.3 $\pm$ 5.8
B 2	8.4 $\pm$ 4.1	16.5 $\pm$ 5.1	0 $\pm$ 0	252.7 $\pm$ 71.6
B 5	11.0 $\pm$ 9.6	13.4 $\pm$ 15.1	0 $\pm$ 0	0 $\pm$ 0
B 6	9.3 $\pm$ 4.7	9.8 $\pm$ 3.1	14.2 $\pm$ 12.9	15.6 $\pm$ 12.6
B 7	14.0 $\pm$ 4.8	17.7 $\pm$ 0.8	0 $\pm$ 0	3.4 $\pm$ 5.9
B 8	11.3 $\pm$ 8.3	29.0 $\pm$ 26.6	0 $\pm$ 0	0 $\pm$ 0
B 9	11.5 $\pm$ 0.5	37.8 $\pm$ 46.3	6.6 $\pm$ 11.4	22.3 $\pm$ 3.1
B10	4.2 $\pm$ 1.7	18.9 $\pm$ 2.0	0 $\pm$ 0	36.1 $\pm$ 8.7
B11	11.5 $\pm$ 5.1	18.7 $\pm$ 9.6	0 $\pm$ 0	3.7 $\pm$ 2.5
B14	5.7 $\pm$ 0.3	90.7 $\pm$ 9.2	0.6 $\pm$ 1.1	12.1 $\pm$ 15.8
B16	10.9 $\pm$ 5.6	10.4 $\pm$ 2.0	2.3 $\pm$ 2.8	5.3 $\pm$ 3.9
B17	11.3 $\pm$ 3.8	9.3 $\pm$ 7.9	0 $\pm$ 0	0 $\pm$ 0
B18	13.0 $\pm$ 0.1	16.1 $\pm$ 1.5	0 $\pm$ 0	77.4 $\pm$ 52.7
B19	1.9 $\pm$ 2.1	26.5 $\pm$ 8.6	8.9 $\pm$ 7.7	25.6 $\pm$ 14.9

Appendix Table 13

Total aerobic heterotrophic bacteria of water from the two study sites during 1978-1979. Values are mean  $\pm$  1 standard deviation.

SITE/ STATION	Total aerobic heterotrophic bacteria/ml water ( $\times 10^2$ )			
	SUMMER	FALL	WINTER	SPRING
A 2	8.4 $\pm$ 1.8	5.7 $\pm$ 0.4	82.0 $\pm$ 14.2	7.1 $\pm$ 1.5
A 5	105.7 $\pm$ 21.5	5.0 $\pm$ 0.4	104.3 $\pm$ 18.0	9.0 $\pm$ 0.8
A 6	12.2 $\pm$ 0.8	32.0 $\pm$ 6.2	145.7 $\pm$ 11.0	10.2 $\pm$ 2.6
A 7	22.2 $\pm$ 1.3	115.3 $\pm$ 36.0	108.0 $\pm$ 15.0	6.1 $\pm$ 0.4
A 8	11.7 $\pm$ 2.3	3.5 $\pm$ 0.2	99.7 $\pm$ 6.8	10.3 $\pm$ 2.4
A 9	11.2 $\pm$ 2.4	3.8 $\pm$ 0.8	72.3 $\pm$ 3.2	12.0 $\pm$ 5.0
A10	10.0 $\pm$ 2.2	4.1 $\pm$ 0.8	63.7 $\pm$ 3.2	8.6 $\pm$ 1.2
A11	11.1 $\pm$ 3.8	10.6 $\pm$ 1.2	208.3 $\pm$ 179.9	5.4 $\pm$ 0.5
A14	25.1 $\pm$ 4.9	2.6 $\pm$ 1.4	90.7 $\pm$ 24.6	6.4 $\pm$ 4.7
A16	140.0 $\pm$ 20.4	4.8 $\pm$ 0.4	132.0 $\pm$ 6.1	138.7 $\pm$ 23.5
A17	14.3 $\pm$ 0.4	7.0 $\pm$ 0.6	97.7 $\pm$ 20.7	7.1 $\pm$ 3.7
A18	10.9 $\pm$ 0.9	3.4 $\pm$ 0.8	84.0 $\pm$ 17.5	16.1 $\pm$ 9.1
A19	77.3 $\pm$ 12.5	4.1 $\pm$ 0.8	72.7 $\pm$ 5.5	8.0 $\pm$ 2.6
B 2	121.7 $\pm$ 50.6	1.0 $\pm$ 0.1	1.7 $\pm$ 0.4	67.3 $\pm$ 5.5
B 5	17.7 $\pm$ 4.5	1.7 $\pm$ 0.3	44.6 $\pm$ 9.5	50.7 $\pm$ 10.0
B 6	139.7 $\pm$ 71.3	3.5 $\pm$ 0.7	67.0 $\pm$ 14.0	13.1 $\pm$ 2.9
B 7	20.8 $\pm$ 5.2	2.2 $\pm$ 0.8	17.9 $\pm$ 2.3	14.8 $\pm$ 6.3
B 8	9.2 $\pm$ 1.8	3.6 $\pm$ 1.2	30.7 $\pm$ 5.0	10.2 $\pm$ 2.4
B 9	13.1 $\pm$ 0.6	2.0 $\pm$ 0.1	33.5 $\pm$ 9.6	10.1 $\pm$ 1.5
B10	7.5 $\pm$ 0.6	1.5 $\pm$ 0.4	82.3 $\pm$ 12.7	47.3 $\pm$ 9.1
B11	10.7 $\pm$ 0.5	2.1 $\pm$ 0.2	48.3 $\pm$ 3.9	10.4 $\pm$ 3.9
B14	47.3 $\pm$ 10.1	1.7 $\pm$ 0.1	114.3 $\pm$ 39.4	98.7 $\pm$ 36.1
B16	71.3 $\pm$ 37.6	2.6 $\pm$ 0.1	72.3 $\pm$ 25.6	87.0 $\pm$ 23.3
B17	16.8 $\pm$ 9.5	3.1 $\pm$ 0.9	20.8 $\pm$ 5.0	11.5 $\pm$ 2.4
B18	11.3 $\pm$ 5.9	3.9 $\pm$ 1.1	2.6 $\pm$ 1.3	15.2 $\pm$ 4.5
B19	51.0 $\pm$ 8.7	3.4 $\pm$ 0.5	30.4 $\pm$ 9.5	13.8 $\pm$ 0.4

Appendix Table 14

Bacterial diversity index of water from the two study sites during 1978-1979. Values are mean  $\pm$  1 standard deviation.

SITE/ STATION	BACTERIAL DIVERSITY INDEX							
	SUMMER		FALL		WINTER		SPRING	
	Index 1	Index 2	Index 1	Index 2	Index 1	Index 2	Index 1	Index 2
A 2	0.84 $\pm$ 0.05	3.48 $\pm$ 0.19	1.99 $\pm$ 0.10	7.97 $\pm$ 0.49	0.60 $\pm$ 0.12	2.28 $\pm$ 0.40	0.55 $\pm$ 0.07	1.98 $\pm$ 0.30
A 5	0.78 $\pm$ 0.32	3.46 $\pm$ 1.67	1.47 $\pm$ 0.14	5.50 $\pm$ 0.63	0.46 $\pm$ 0.09	1.83 $\pm$ 0.34	0.59 $\pm$ 0.08	2.38 $\pm$ 0.31
A 6	0.91 $\pm$ 0.12	4.32 $\pm$ 0.53	1.77 $\pm$ 0.05	5.99 $\pm$ 0.36	0.80 $\pm$ 0.07	4.00 $\pm$ 0.47	0.56 $\pm$ 0.04	2.32 $\pm$ 0.20
A 7	0.65 $\pm$ 0.03	3.67 $\pm$ 0.21	1.11 $\pm$ 0.16	5.22 $\pm$ 0.45	0.61 $\pm$ 0.14	2.62 $\pm$ 0.73	0.89 $\pm$ 0.11	3.34 $\pm$ 0.51
A 8	1.31 $\pm$ 0.18	6.31 $\pm$ 0.59	2.15 $\pm$ 0.42	7.57 $\pm$ 1.61	0.57 $\pm$ 0.11	2.33 $\pm$ 0.57	0.52 $\pm$ 0.03	2.15 $\pm$ 0.18
A 9	0.72 $\pm$ 0.07	3.25 $\pm$ 0.60	1.48 $\pm$ 0.20	5.10 $\pm$ 0.61	0.66 $\pm$ 0.12	2.51 $\pm$ 0.59	0.48 $\pm$ 0.16	1.96 $\pm$ 0.55
A10	0.88 $\pm$ 0.22	3.87 $\pm$ 0.87	1.73 $\pm$ 0.31	6.23 $\pm$ 0.90	0.55 $\pm$ 0.20	1.86 $\pm$ 0.87	0.57 $\pm$ 0.03	2.23 $\pm$ 0.22
A11	0.86 $\pm$ 0.25	3.81 $\pm$ 0.83	1.21 $\pm$ 0.16	5.61 $\pm$ 0.65	0.39 $\pm$ 0.17	1.70 $\pm$ 0.48	0.58 $\pm$ 0.06	1.92 $\pm$ 0.29
A14	0.74 $\pm$ 0.13	4.45 $\pm$ 0.91	1.52 $\pm$ 0.52	4.55 $\pm$ 1.13	0.62 $\pm$ 0.13	2.53 $\pm$ 0.88	0.61 $\pm$ 0.22	1.96 $\pm$ 0.51
A16	0.65 $\pm$ 0.09	3.12 $\pm$ 0.34	1.65 $\pm$ 0.30	6.18 $\pm$ 1.06	0.55 $\pm$ 0.10	2.51 $\pm$ 0.54	0.14 $\pm$ 0.02	1.48 $\pm$ 0.21
A17	0.97 $\pm$ 0.06	4.34 $\pm$ 0.14	1.67 $\pm$ 0.14	7.04 $\pm$ 0.56	0.73 $\pm$ 0.18	3.16 $\pm$ 1.12	0.50 $\pm$ 0.14	1.67 $\pm$ 0.22
A18	1.09 $\pm$ 0.24	5.09 $\pm$ 1.11	1.49 $\pm$ 0.16	5.02 $\pm$ 0.40	0.48 $\pm$ 0.12	1.75 $\pm$ 0.39	0.41 $\pm$ 0.13	1.85 $\pm$ 0.50
A19	1.04 $\pm$ 0.20	4.26 $\pm$ 0.69	1.63 $\pm$ 0.12	5.82 $\pm$ 0.27	0.55 $\pm$ 0.10	2.62 $\pm$ 0.55	0.50 $\pm$ 0.17	1.79 $\pm$ 0.48
B 2	0.96 $\pm$ 0.02	4.50 $\pm$ 0.59	1.39 $\pm$ 0.46	3.37 $\pm$ 1.49	1.21 $\pm$ 0.11	3.25 $\pm$ 0.54	0.22 $\pm$ 0.04	1.76 $\pm$ 0.35
B 5	0.95 $\pm$ 0.10	5.18 $\pm$ 0.91	1.70 $\pm$ 0.52	4.87 $\pm$ 1.89	0.40 $\pm$ 0.04	2.78 $\pm$ 0.21	0.22 $\pm$ 0.04	1.47 $\pm$ 0.37
B 6	0.79 $\pm$ 0.23	3.87 $\pm$ 1.64	1.68 $\pm$ 0.35	5.81 $\pm$ 1.52	0.20 $\pm$ 0.06	0.36 $\pm$ 0.31	0.44 $\pm$ 0.11	1.90 $\pm$ 0.52
B 7	0.84 $\pm$ 0.08	4.76 $\pm$ 0.33	1.78 $\pm$ 0.16	5.46 $\pm$ 0.94	0.48 $\pm$ 0.10	2.37 $\pm$ 0.54	0.63 $\pm$ 0.16	2.97 $\pm$ 0.48
B 8	1.32 $\pm$ 0.17	5.93 $\pm$ 1.08	1.34 $\pm$ 0.08	4.51 $\pm$ 0.71	0.35 $\pm$ 0.15	0.66 $\pm$ 0.64	0.55 $\pm$ 0.13	2.31 $\pm$ 0.71
B 9	1.08 $\pm$ 0.03	5.34 $\pm$ 0.22	2.10 $\pm$ 0.62	6.43 $\pm$ 2.05	0.30 $\pm$ 0.03	1.72 $\pm$ 0.17	0.59 $\pm$ 0.06	2.49 $\pm$ 0.08
B10	1.32 $\pm$ 0.46	5.54 $\pm$ 1.97	1.49 $\pm$ 0.43	4.02 $\pm$ 1.33	0.22 $\pm$ 0.02	0.52 $\pm$ 0.02	0.16 $\pm$ 0.03	0.99 $\pm$ 0.21
B11	1.16 $\pm$ 0.41	5.42 $\pm$ 2.13	1.67 $\pm$ 0.39	5.05 $\pm$ 1.27	0.21 $\pm$ 0.03	1.37 $\pm$ 0.23	0.50 $\pm$ 0.10	1.99 $\pm$ 0.48
B14	0.93 $\pm$ 0.16	3.19 $\pm$ 0.65	1.87 $\pm$ 0.63	5.43 $\pm$ 2.20	0.35 $\pm$ 0.02	1.30 $\pm$ 0.19	0.17 $\pm$ 0.04	1.54 $\pm$ 0.63
B16	0.99 $\pm$ 0.10	3.84 $\pm$ 0.48	1.32 $\pm$ 0.31	4.02 $\pm$ 1.11	0.30 $\pm$ 0.14	0.86 $\pm$ 0.78	0.15 $\pm$ 0.04	1.24 $\pm$ 0.49
B17	0.94 $\pm$ 0.31	4.77 $\pm$ 1.01	1.22 $\pm$ 0.36	3.84 $\pm$ 1.32	0.39 $\pm$ 0.06	2.00 $\pm$ 0.58	0.56 $\pm$ 0.13	2.44 $\pm$ 0.54
B18	1.22 $\pm$ 0.23	5.64 $\pm$ 0.51	1.50 $\pm$ 0.30	5.25 $\pm$ 1.32	0.92 $\pm$ 0.31	2.50 $\pm$ 0.75	0.30 $\pm$ 0.04	1.22 $\pm$ 0.24
B19	2.08 $\pm$ 0.39	8.06 $\pm$ 1.22	1.54 $\pm$ 0.33	5.22 $\pm$ 1.26	0.19 $\pm$ 0.02	0.94 $\pm$ 0.19	0.33 $\pm$ 0.08	1.39 $\pm$ 0.47

Appendix Table 15

Heterotrophic activity ( $^{14}\text{C}$ -(U) glucose uptake) of bacteria of water from the two study sites during 1978-1979. Values are mean  $\pm$  1 standard deviation.

SITE/ STATION	$^{14}\text{C}$ -(U) glucose uptake rate (dpm/ml/hr)			
	SUMMER	FALL	WINTER	SPRING
A 2	3.6 $\pm$ 3.4	14.2 $\pm$ 18.6	-	9.7 $\pm$ 5.4
A 5	0.5 $\pm$ 0.9	1.5 $\pm$ 0.9	-	0.5 $\pm$ 0.5
A 6	9.0 $\pm$ 15.2	15.3 $\pm$ 10.8	5.47 $\pm$ 1.22	69.3 $\pm$ 120.1
A 7	37.1 $\pm$ 28.7	6.6 $\pm$ 5.6	6.39 $\pm$ 0.51	1.1 $\pm$ 0.4
A 8	8.7 $\pm$ 8.9	6.0 $\pm$ 1.5	22.69 $\pm$ 17.18	17.5 $\pm$ 29.0
A 9	17.4 $\pm$ 24.7	0.8 $\pm$ 0.4	42.57 $\pm$ 61.52	0 $\pm$ 0
A10	5.0 $\pm$ 2.9	3.3 $\pm$ 1.6	5.34 $\pm$ 1.13	4.5 $\pm$ 6.6
A11	6.0 $\pm$ 6.4	30.9 $\pm$ 53.6	0 $\pm$ 0	0 $\pm$ 0
A14	10.3 $\pm$ 7.7	9.2 $\pm$ 6.4	0 $\pm$ 0	0.5 $\pm$ 0.2
A16	0 $\pm$ 0	6.4 $\pm$ 3.2	4.42 $\pm$ 0.54	0 $\pm$ 0
A17	28.9 $\pm$ 42.0	3.3 $\pm$ 5.8	7.10 $\pm$ 2.46	6.8 $\pm$ 2.2
A18	8.6 $\pm$ 2.9	8.1 $\pm$ 8.1	0 $\pm$ 0	1.0 $\pm$ 0.6
A19	8.0 $\pm$ 13.3	14.5 $\pm$ 19.7	6.92 $\pm$ 11.99	2.5 $\pm$ 1.6
B 2	2.5 $\pm$ 0.5	0 $\pm$ 0	0.85 $\pm$ 0.22	11.0 $\pm$ 6.1
B 5	3.6 $\pm$ 0.9	0 $\pm$ 0	0.88 $\pm$ 0.11	10.8 $\pm$ 17.3
B 6	0.8 $\pm$ 0.8	1.2 $\pm$ 0.4	5.76 $\pm$ 2.25	4.2 $\pm$ 7.2
B 7	0 $\pm$ 0	0.1 $\pm$ 0.1	6.99 $\pm$ 6.65	47.2 $\pm$ 41.6
B 8	3.6 $\pm$ 3.4	0.1 $\pm$ 0.1	0.99 $\pm$ 0.24	2.9 $\pm$ 1.3
B 9	4.8 $\pm$ 0.6	0 $\pm$ 0	1.50 $\pm$ 0.60	403.7 $\pm$ 353.4
B10	1.2 $\pm$ 0.6	0 $\pm$ 0	0 $\pm$ 0	130.7 $\pm$ 181.0
B11	0 $\pm$ 0	0 $\pm$ 0	1.74 $\pm$ 0.49	353.9 $\pm$ 443.0
B14	12.0 $\pm$ 10.9	0 $\pm$ 0	6.39 $\pm$ 4.89	296.3 $\pm$ 474.2
B16	3.7 $\pm$ 4.8	0 $\pm$ 0	90.89 $\pm$ 151.22	77.6 $\pm$ 91.1
B17	0.4 $\pm$ 0.7	0.1 $\pm$ 0.0	2.08 $\pm$ 0.36	0 $\pm$ 0
B18	0 $\pm$ 0	0 $\pm$ 0	0.39 $\pm$ 0.11	0 $\pm$ 0
B19	3.9 $\pm$ 1.8	0 $\pm$ 0	0.04 $\pm$ 0.01	124.3 $\pm$ 215.2

Appendix Table 16

Heterotrophic activity ( $^{14}\text{C}$ -(U) glucose mineralization) of bacteria of water from the two study sites during 1978-1979. Values are mean  $\pm$  1 standard deviation.

SITE/ STATION	$^{14}\text{C}$ -(U) glucose mineralization rate (dpm/ml/hr)			
	SUMMER	FALL	WINTER	SPRING
A 2	0 $\pm$ 0	2.2 $\pm$ 2.4	-	2.6 $\pm$ 2.6
A 5	-	1.4 $\pm$ 1.6	-	0 $\pm$ 0
A 6	0 $\pm$ 0	3.6 $\pm$ 5.1	0.28 $\pm$ 0.31	0 $\pm$ 0
A 7	0.6 $\pm$ 0.8	1.7 $\pm$ 0.9	0.83 $\pm$ 1.44	1.3 $\pm$ 2.3
A 8	6.7 $\pm$ 5.0	1.9 $\pm$ 0.3	0 $\pm$ 0	2.6 $\pm$ 4.5
A 9	1.3 $\pm$ 1.3	0.1 $\pm$ 0.1	1.96 $\pm$ 0.81	2.6 $\pm$ 4.6
A10	2.0 $\pm$ 2.9	2.7 $\pm$ 2.6	1.14 $\pm$ 0.52	1.5 $\pm$ 2.6
A11	0 $\pm$ 0	0 $\pm$ 0	5.03 $\pm$ 6.70	6.1 $\pm$ 4.9
A14	3.7 $\pm$ 4.8	0.6 $\pm$ 0.5	1.73 $\pm$ 1.92	0.1 $\pm$ 0.1
A16	0 $\pm$ 0	0.5 $\pm$ 0.4	0 $\pm$ 0	2.5 $\pm$ 1.9
A17	0.3 $\pm$ 0.6	0.8 $\pm$ 0.5	0 $\pm$ 0	1.1 $\pm$ 1.6
A18	9.9 $\pm$ 13.6	0.6 $\pm$ 1.0	0.42 $\pm$ 0.36	1.5 $\pm$ 2.0
A19	1.2 $\pm$ 1.7	0.5 $\pm$ 0.2	1.00 $\pm$ 1.73	0.6 $\pm$ 0.5
B 2	3.3 $\pm$ 4.7	0.3 $\pm$ 0.3	3.70 $\pm$ 6.41	5.8 $\pm$ 6.7
B 5	0 $\pm$ 0	0 $\pm$ 0	0.58 $\pm$ 0.45	0 $\pm$ 0
B 6	0.2 $\pm$ 0.3	0.6 $\pm$ 1.0	0 $\pm$ 0	0 $\pm$ 0
B 7	0 $\pm$ 0	0.6 $\pm$ 0.5	3.05 $\pm$ 4.43	3.7 $\pm$ 6.4
B 8	1.8 $\pm$ 2.7	0.8 $\pm$ 0.5	0 $\pm$ 0	1.8 $\pm$ 3.1
B 9	0 $\pm$ 0	7.5 $\pm$ 12.4	20.90 $\pm$ 18.64	0 $\pm$ 0
B10	4.9 $\pm$ 7.2	0.9 $\pm$ 0.9	1.14 $\pm$ 0.89	0.6 $\pm$ 0.7
B11	2.4 $\pm$ 2.4	0 $\pm$ 0	0 $\pm$ 0	2.3 $\pm$ 2.0
B14	3.0 $\pm$ 5.2	1.0 $\pm$ 0.8	0.24 $\pm$ 0.28	5.1 $\pm$ 8.8
B16	0.4 $\pm$ 0.7	0 $\pm$ 0	1.19 $\pm$ 0.82	1.4 $\pm$ 2.4
B17	5.0 $\pm$ 4.4	0.6 $\pm$ 0.6	0 $\pm$ 0	5.5 $\pm$ 1.9
B18	0 $\pm$ 0	1.8 $\pm$ 1.2	0.21 $\pm$ 0.35	2.1 $\pm$ 0.9
B19	0 $\pm$ 0	0.1 $\pm$ 0.1	3.32 $\pm$ 5.49	3.3 $\pm$ 4.6

## APPENDIX B

### List of Works in Progress Resulting from the Contract

1. Hydrocarbon degrading bacteria from offshore regions of the Gulf of Mexico.